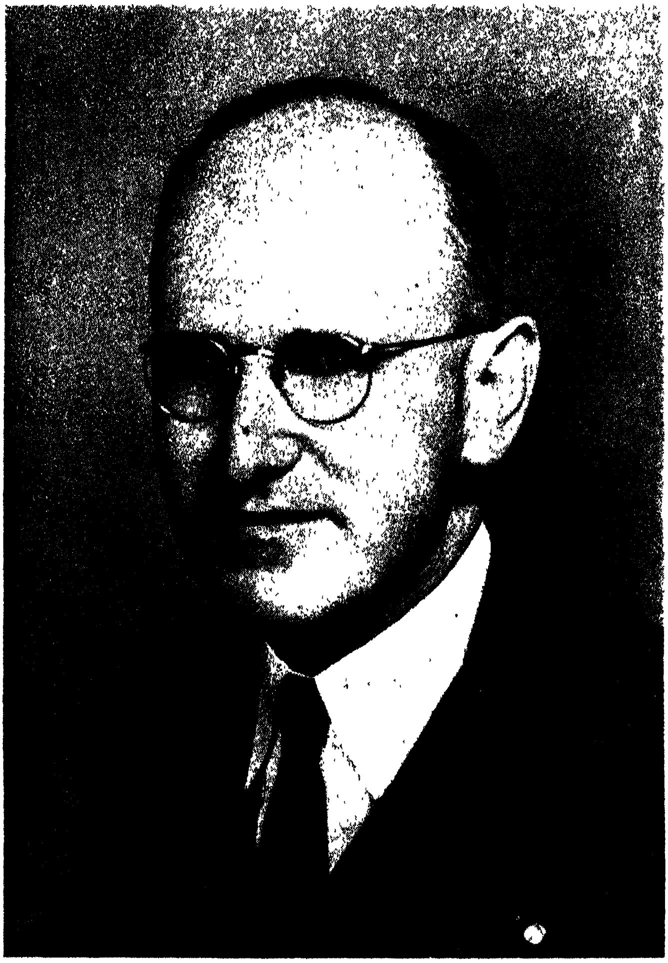

J. E. Knott

PROCEEDINGS

OF THE

AMERICAN SOCIETY

FOR

HORTICULTURAL SCIENCE

VOLUME 52

H. B. Tukey, Editor and Business Manager
Michigan State College,
East Lansing, Michigan

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CONTENTS

PAGE

Officers and Committees vii
Constitution and By-Laws viii
Society Affairs xi

The Determination of Calcium and Magnesium in Leaves Using Flame Methods and a Quartz Spectrophotometer, by J. G. Brown, O. Lilleland and R. K. Jackson 1
Potassium, Calcium, and Magnesium Content in Citrus Flowers Collected from Trees on Various Rootstocks, by A. R. C. Haas 7
The Nutrition of Tung Trees, by F. S. Lagasse and M. Drosdoff 11
Responses of Bearing Tung Trees on Red Bay Fine Sandy Loam to Potassium and Nitrogen, by J. H. Painter, M. Drosdoff and R. T. Brown 19
Response of Bearing Tung Trees to Nitrogen, Phosphorus, and Potassium Fertilizers, by B. G. Sitton 25
Further Work on Leaf Nitrogen and Leaf Color as Measures of the Nitrogen Status of Fruit Trees, by D. Boynton, O. C. Compton and E. Fisher 40
Foliar Diagnosis: The Mineral Nutrition of Peach Trees with Particular Reference to Bacterial Leaf Spot, by W. Thomas, W. B. Mack and F. N. Fagan 47
Color as an Index of Nitrogen Content of Leaves of York and Stayman Apples, by G. M. Shear and F. Horsfall Jr. 57
Potassium Content of Various Parts of the Peach Tree and Their Correlation with Potassium Fertilization — A Sampling Study, by D. E. H. Frear, R. D. Anthony, A. L. Haskins, and F. N. Hewetson 61
Factors Affecting Branching and Growth of Newly Transplanted Tung Trees Trained to Vase Form, by M. S. Neff, and J. H. Painter 75
Recent Research in Breeding and Selection of Tung, by W. W. Kilby 81
Response of Peach Trees to Boron, by C. F. Williams and O. Veerhoff 88
Effect of Different Seedling Rootstocks on Growth, Production, and Nutrient Absorption of Tung Clones, by M. S. Neff, M. Drosdoff, and R. Sharpe 97
Notes on the Growth of Persian Walnut Propagated on Rootstocks of the Chinese Wing-Nut, Pterocarya Stenoptera, by W. E. Whitehouse and L. E. Joley 103
Relative Variability of Fruits of Seedling and Budded Tung Trees, by F. S. Lagasse, G. F. Potter, and G. H. Blackmon 107
Peach Fruit Bud Hardiness as Affected by Blossom Thinning Treatments, by L. J. Edgerton 112
Cold Injury to Dormant Buds of Two Tung Varieties and Its Effect on Yields, by R. D. Dickey 115
More than Thirty Peach Varieties Survived Minus Thirty-Two Degrees Fahrenheit, by R. W. Campbell 117
Some Artificial Freezing Tests of Peach Fruit Buds, by C. E. Chaplin 121
The Nature of Giant Apple Sports and Their Use in Breeding *(Abstract)*, by G. M. Darrow, R. A. Gibson, W. E. Toenjes and H. Dermen 130
The Effect of Severity of Pruning on the Performance of Young Elberta Peach Trees, by A. D. Hibbard 131
Further Scion and Stock Combinations with Spy 227, by W. D. Weeks 137
Peach Variety Incompatibilities on Seedlings of a Yunnan Understock, by J. T. Bregger 141
Ascorbic Acid Content of 33 Peach Varieties in Relation to Genetic and Environmental Factors, by Q. Zielinski 143
Some Effects of Harvesting Methods and Container Performance on Keeping Quality of Louisiana Peaches, by D. C. Alderman 149
Frost Injury to Apples in the Autumn, by A. F. Yeager and E. J. Rasmussen 157
The Storage and Ripening Response of Western-Grown Fruits to Post-Harvest Treatment with Growth-Regulating Substances, by F. Gerhardt and E. Smith 159

PAGE
Three Years' Results with Chemical Thinning of Apples in the Northwest, by L. P. Batjer and A. H. Thompson 164
Relative Humidity for Storing Dates at Different Temperatures, by G. L. Rygg 173
A Study of Maturity Indices for McIntosh Apples, by R. M. Smock 176
A Multiple Chamber Pressure Unit for Respiration Studies, by E. K. Alban and H. W. Ford 183
Respiration of Citrus Fruits in Relation to Metabolism of Fungi. II Effects of Emanations of Penicillium Digitatum Sacc. on Lemons at Different Stages of Ripeness, by J. B. Biale 187
Modified Atmospheres in Relation to the Storage Life of Bartlett Pears, by F. W. Allen and L. L. Claypool 192
An Air Purification Trial in a Wenatchee Apple Storage, by A. Van Doren 205
Seasonal Incidence of Perfect and Staminate Olive Flowers, by R. M. Brooks 213
Further Studies on Air Purification in the Apple Storage, by F. W. Southwick and R. M. Smock 219
Morphological Development of Parthenocarpic Fruits, by L. K. Mann 226
Parthenocarpy in Caprifigs, by I. J. Condit 233
The Use of Growth-Regulating Chemicals to Induce Parthenocarpic Fruit in the Calimyrna Fig *(Abstract)*, by J. C. Crane 236
Fruit Growth of Four Fig Varieties as Measured by Diameter and Fresh Weight, by J. C. Crane 237
Specific Gravity of Citrus Fruits, by F. M. Turrell and D. L. Slack 245
The Ascorbic Acid Content of Nine Strawberry Varieties in Mississippi, by J. P. Overcash and L. McWhirter 251
The Keeping Quality of "Pre-Packaged" Fresh Cranberries, by K. M. Hayes, C. R. Fellers, and W. B. Esselen, Jr. 257
A New Fall Bearing Red Raspberry, Durham — and the Spur Blight Problem, by A. F. Yeager and M. C. Richards 263
A Study of the Rest Period in Red Raspberries, by J. S. Bailey 265
A Study of the Effects of a–Naphthaleneacetic Acid on Prolongation of Rest in the Latham Raspberry, by J. S. McCartney 271
A Note on the Inheritance of Flower Type in Muscadine Grapes, by N. H. Loomis 276
Control of Grape Root-Rot in Solution Culture, by W. O. Williams and W. B. Hewitt 279
Magnesium Injection in Muscadine Grape Vines, by W. L. Lott 283
Propagation of the Rabbiteye Blueberry, by W. T. Brightwell 289
Some Factors Affecting the Success of Green Wood Grafting of Grapes, by F. N. Harmon and E. Snyder 294
Further Observations on the Control of Mummy Berry on Cultivated Blueberries, by J. S. Bailey 299
A Sweetpotato from Tinian Island Highly Resistant to Fusarium Wilt, by C. E. Steinbauer 304
Baking Sweet Potato Tests in Hawaii, by C. F. Poole 307
Preliminary Studies on the Top System of the Bunch Porto Rico Sweet Potato, by S. A. Harmon 311
Effects of Rates of Nitrogen on the Relative Yields of Sweetpotato Vines and Roots, by W. A. Johnson and L. M. Ware 313
Effects of Organic Materials, Fertilizers, and Irrigation on the Yields of Sweetpotatoes, by L. M. Ware and W. A. Johnson 317
Effect of Length of Exposure to Sun on Keeping of Sweet Potatoes, by C. A. Miller and W. D. Kimbrough 322
The Occurrence of Bacterial Soft Rot on Potatoes Resulting from Washing in Deep Vats, by D. H. Dewey and W. R. Barger 325
Some Observations on Another Species of Cultivated Pepper, Capsicum Pubescens R & P, by C. B. Heiser and P. G. Smith 331
Bacterial Spot Resistance in Peppers, by J. A. Martin 336
Climate and the Question of Time in Tomato Improvement, by W. A. Frazier, K. Kikuta, and J. W. Hendrix 341
Culture of Solanum Nigrum Embryos, by C. B. Hall 343

PAGE

Nutrient-Element Balance and Time of Anthesis in Tomato Flowers, by V. N. Lambeth 347
Effect of Plant Training and Number of Pollinations per Cluster on Production of F_1 Hybrid Tomato Seed in the Greenhouse, by E. A. Wolf and E. C. Stair 350
The Description and Inheritance of a Functionally Sterile Flower Mutant in Tomato and Its Probable Value in Hybrid Tomato Seed Production, by R. E. Larson and S. Paur 355
Effects on Tomatoes of Field Application of Two Hormone-Insecticide-Fungicide Mixtures, by E. F. Paddock 365
Effect of Sprout Preventive Treatments on Fall-Harvested Kohlrabi, Potatoes, Sweetpotatoes, and Turnips while in Storage, by C. L. Isbell 368
The Southern Tomato Exchange Program, by S. H. Yarnell 375
Effect of Frequency of Picking Tomatoes on Yield and Returns, by J. Hartman and E. Oesterle 383
A Preliminary Report on the Effect of Various Cultural Practices with Greenhouse Tomatoes on the Respiration Rate of the Harvested Fruit, by E. K. Alban, F. W. Ford, and F. S. Howlett 385
The Effect of Holding Treatments Prior to Canning on the Vitamin Content and Palatability of Certain Vegetables *(Abstract)*, by R. E. Marshall, Pauline Paul, Margaret Ohlsen, and W. F. Robertson 391
Storage of Vine-Ripened Tomatoes, by L. E. Scott 393
Effect of Some Sodium Salts and Rate of Seeding on the Yield and Color of Beets *(Abstract)*, by C. B. Sayre and M. T Vittum 398
The Inheritance of Two Characters of Cucumis Melo and their Interrelationship, by M. B. Hughes 399
The Use of Naked Seed in Cucurbita Pepo as a Source of High Quality Liquid Vegetable Fat, as a High Analysis Protein, as a new Confection, and as a Sandwich Spread, by L. C. Curtis 403
Onion Curing — A Comparison of Storage Losses from Artificial, Field, and Non-Cured Onions, by B J. Hoyle 407
Color Specification of the Federal Canning Tomato Grade as Related to Horticultural Color Determination, by J. H. MacGillivray 415
Comparative Yields of Seven Varieties of Pumpkins (Cucurbita Moschata) Adapted to the South, by W. H. Greenleaf 430
The Effects of Bud Pollination on Fertility and F_1 Fruit Characters of Some Chinese Brassicas, by S. H. Lee 435
Vernalization and Seed Stem Development in Lettuce, by R. C. Thompson and W Kosar 441
Correlation of Soil Test Results with Celery Plant Growth, by J. F. Davis and K. Lawton 443
Effect of Hormone Sprays on Yield of Snap Beans, by G. S. Randhawa and H C. Thompson 448
Effect of DDT Insecticides on Plant Growth and Yield of Some Bush Lima Bean Varieties, by R. E. Wester and C. A. Weigel 453
Herbicides for Control of Weeds in Vegetable Seedbeds also Control Root-Knot, by D. S Burgis and J. R. Beckenbach 461
Nutrient-Element Balance and Growth of Leaf Lettuce, by R. A. Schroeder 464
Nematode Control in Nutriculture, by W. R. Mullison 467
Observations on the Storage and Germination Characteristics of Angelica Seed, by C. A. Taylor 471
The Flowering Response of the Veitch Gardenia to Long-Day Treatment, by E. W. McElwee 475
Interrupted Shading of Chrysanthemums, by D. C. Kiplinger and J. Alger 478
Inheritance of Resistance to Rust in the Snapdragon, Antirrhinum Majus L., by G. A. L. Mehlquist and R. Rahmani 481
Effect of Nitrogen and Potash Fertilization on Patrician Carnations in Soil, by G. Beach and A. Mussenbrock 487
The Incidence of Blindness in the Better Times Rose, by J. R. Kamp 490
Pollination Requirements of English Holly, Ilex Aquifolium, by A. N. Roberts and C. A. Boller 501

PAGE

Cytogenetic Studies on Rosa Rubiginosa L. and its Hybrids, by H. T. Blackhurst 510
The Effect of Mulches and Companion Crops on Soil Aggregation and Porosity and on the Growth of Some Woody Ornamental Plants in the Garden and Nursery, by F. Galle and L. C. Chadwick 517
Notes on Growth Habits and Pinching of Hydrangeas, by C. W. Dunham and R. H. Roberts 525
The Effect of Various Amounts of Potassium on the Production and Growth of Better Times Roses Under Glass, by J. R. Culbert and E. J. Wilde ... 528
Looking Ahead in Horticulture, by Otis Woodard 537
Cooperation in Vegetable Research (Presidential Address) by J. E. Knott 542
Membership Roll 549
Index 570

OFFICERS AND COMMITTEES

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CONSTITUTION*

ARTICLE I

The name of this Association shall be the American Society for Horticultural Science.

ARTICLE II

The object of the Society shall be to promote the Science of Horticulture.

ARTICLE III

Voting members: Any person who has a baccalaureate degree and holds an official position in any agricultural college, experiment station, or federal or state department of agriculture in the United States or Canada, is eligible to membership. Other applicants may be admitted by vote of the executive committee.

Associate Members: Any person not eligible to voting membership will be eligible to associate membership upon vote of the executive committee. Associate members shall not vote and will present papers only at the request of the program committee.

ARTICLE IV

Meetings shall be held annually at such time and place as may be designated by the Executive Committee, unless otherwise ordered by the Society.

ARTICLE V

The officers shall consist of a President, a Vice-President, a Secretary-Treasurer, and sectional chairmen to represent the subject-matter sections of the Society.

ARTICLE VI

The Constitution may be amended by a two-thirds vote of the Society at any regular meeting, notice of such amendment having been read at the last regular meeting.

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*As revised and adopted at the Boston meeting, December 29, 1946.

BY-LAWS

Section 1—*Duties of Officers:* The President shall preside at business meetings and general sessions of the society, deliver an address at the regular annual meeting, and serve *ex officio* as a member of the executive committee.

The Vice-President shall preside at business meetings and general sessions of the Society in the absence of the President and serve *ex officio* as a member of the executive committee.

The Sectional Chairmen shall preside at sectional meetings and serve *ex officio* as members of the executive committee.

The Secretary-Treasurer shall keep the records of the Society; mail to members a call for papers for the annual meeting at least 30 days prior to closing date for acceptance of papers, and at least 3 months prior to the annual meeting shall request of members suggestions regarding nominations, matters of policy and general welfare of the Society; serve *ex officio* as a member of the executive and program committees; collect dues from members; and conduct the financial affairs of the Society with the aid and advice of the chairman of the executive committee.

Section 2—*Executive Committee:* There shall be an executive committee consisting of the retiring President, who shall be chairman, the President, the Vice-President, the Sectional Chairmen, the chairmen of regional groups, the Secretary-Treasurer, the Editor-Business Manager, and two members elected at large for terms of two years each, retiring in alternate years. This committee shall act for the Society in the interim between annual meetings; shall fix the date for the annual meeting; shall present at each annual meeting nominees for members of the nominating committee; shall act on admission of all associate members, regional groups and junior branches and in special cases may elect to voting membership persons of high qualifications but otherwise ineligible; shall consider matters of general policy or welfare of the organization and present its recommendations at the annual meeting of the Society.

Section 3—*Nominating Committee:* There shall be a committee on nominations consisting of two members from each of the sectional groups who shall be nominated by the executive committee and elected by ballot at each annual meeting of the Society. It shall be the duty of this committee, at the following annual meeting to present a list of nominees for the various offices, committees (except the Nomination Committee), representatives, and sectional chairmen who shall be selected after consultation with the sections. This committee shall also nominate referees and alternates upon special subjects of investigation or instruction which may be referred to it for consideration by the Society. The duties of these referees shall be to make concise reports upon recent investigations or methods of teaching in the subjects assigned to them and to report the present status of the same.

Section 4—*Program Committee:* There shall be a committee on program consisting of five (5) members, including the Secretary and the Editor. This committee shall have charge of the scientific activities of the Society, except as otherwise ordered by the Society. It shall receive titles and arrange the program of the annual meeting; arrange symposia; accept or reject titles, and may invite non-members to participate.

Section 5—*Editorial Committee.* There shall be an Editorial Committee consisting of five members. One member shall be elected each year to serve for five years. It shall be the duty of this committee to formulate the editorial and publication policies of the Society; to assist the Editor in reviewing and editing papers and shall have final authority to reject any paper deemed not worthy or unsuitable for publication in the PROCEEDINGS. The Committee at the call of the senior member shall elect a chairman from among its members, who shall serve for the calendar year.

The Committee shall appoint an Editor and Business Manager of the PROCEEDINGS, subject to the approval of the Executive Committee. He shall serve for a period of 3 calendar years, and shall be charged with editing, publishing and

distributing the PROCEEDINGS. He shall serve *ex officio* as a member of the Executive Committee.

Section 6—*Membership Committee:* There shall be a committee on membership whose duties shall be the promotion of membership in the Society.

Section 7—*Auditing Committee:* There shall be a committee to audit the books of the Society and report their condition at each annual meeting.

Section 8—*Committee on Local Arrangements:* There shall be a committee on local arrangements who in cooperation with the Secretary-Treasurer will have charge of all local arrangements for the annual meeting.

Section 9—*Quorum:* Ten members of the Society shall constitute a quorum for the transaction of business at a regularly called meeting of which at least 30 days notice shall have been given to members.

Section 10—*Annual Dues:* The annual dues of the Society shall be six dollars.

Section 11—*Amendment to the By-Laws:* The by-laws may be amended at any regular meeting by a two-thirds vote of members present providing a copy of such amendment has been sent to all members at least 30 days prior to the meeting.

Section 12—*Regional Groups:* Upon the presentation of a petition signed by ten or more members of this Society residing within a stated region, the executive committee may approve the formation of a regional group affiliated with this Society. Such group must elect as a minimum number of officers as chairman, a vice-chairman and a secretary and shall present an annual report to the Secretary-Treasurer of the national Society to include the names of its officials and a review of its meetings or other activities. Publication of this report in full or in part shall be made in the PROCEEDINGS of this Society. Papers presented at regional group meetings may be published on the same basis as papers presented at the regular annual meeting.

Section 13—*Junior Branches:* A student horticultural group at a college or university, operating under the supervision of a member or members of this Society, may organize as a Junior Branch of the American Society for Horticultural Science upon approval of the executive committee and the payment of an annual fee of six dollars for the branch. Each branch shall receive a copy of all publications of the Society. Such a branch shall elect a chairman, a vice-chairman and a secretary-treasurer and shall present an annual report of its activities to the national Secretary-Treasurer. Such groups may hold meetings in conjunction with the annual meetings of this Society and a report of such meetings, not including individual papers, may be included in the PROCEEDINGS.

Section 14—*Term of service for elected officers:* The term of service for elected officers shall be from the close of the annual meeting at which they are elected until the close of the next annual meeting.

SOCIETY AFFAIRS

REPORT OF THE EXECUTIVE COMMITTEE MEETING, CINCINNATI, OHIO, SEPTEMBER 7, 1948

The Executive Committee of the American Society for Horticultural Science met in the Hotel Gibson, September 7, 1948, with the following members in attendance: J. E. Knott, G. M. Darrow, F. S. Howlett, E. S. Haber, G. A. L. Mehlquist, R. E. Marshall, H. A. Rollins, A. F. Yeager, L. L. Claypool for L. D. Davis, W. S. Anderson for J. B. Edmond, S. H. Cameron and H. B. Tukey, chairman.

The report of the Secretary-Treasurer was presented. The membership in the Society was given as approximately 1,250 or a gain of 250 since January 1, 1947. The financial affairs of the Society were reported to be in good condition and an audit as of September 1, 1948, was presented.

The report of the editor of the PROCEEDINGS was presented by Dr. H. B. Tukey. The matter of publishing a journal rather than the PROCEEDINGS was discussed but no decision was reached and the matter was deferred for the present.

The Executive Committee reaffirmed the fact that membership in the Society be limited to individuals, and the Secretary was instructed to inquire into instances where commercial firms are paying the individual rate for volumes of the PROCEEDINGS, rather than the regular $12.00 library rate.

There was a discussion of the qualifications for active and associate membership. The Chairman of the Executive Committee was authorized to appoint a committee to submit a proposal to the business session of the Society for change of Article 3 of the Constitution dealing with qualifications for membership. The committee appointed was G. M. Darrow, Chairman; W. S. Anderson, and G. A. L. Mehlquist.

The representative of the Society on the Governing Board of the American Institute of Biological Sciences, Dr. Frank Cullinan reported on the present status of the new organization The Executive Committee voted that the Society ask the American Institute of Biological Sciences to consider the possibility of arranging for group meetings of the Biological Societies beginning in 1950 and urged that the AIBS consider a five-year program for the Society.

There was discussion of the Leonard H Vaughan Memorial Awards, with the conclusion that these awards fulfilled a very worth-while function in the Society.

The Nominating Committee for 1949 was proposed as follows: R. E. Marshall, *Chairman*, L. L. Davis, F. S. Jamison, O. A. Lorenz, H. A. Rollins, T. A. Merrill, E. W. McElwee, and J. G. Seeley.

REPORT OF THE GENERAL BUSINESS SESSION, CINCINNATI, OHIO, SEPTEMBER 10, 1948

The Annual Business session of the Society was held September 10, 1948, in the Hotel Gibson, Cincinnati, Ohio. Two hundred members were in attendance, the highest number for some years.

The report of the Secretary-Treasurer was presented and accepted.

The report of the Executive Committee meeting was presented by the chairman, H. B. Tukey, and was accepted.

The report of the Editor-Business Manager of the PROCEEDINGS was presented and accepted.

The reports of the Program committee was received and the Chairman, J. T. McCollum recommended that the procedure followed in 1948 for the first time of appointing three members of the committee for the same institution be continued.

The Editorial committee presented its report which was accepted. The contents of this report are given below.

The Membership committee reported that the campaign for new associate and active members was yielding very favorable results, a fact confirmed by the Secretary-Treasurer. Two new Junior Branch memberships were reported — Washington State and Tennessee.

The report of the representative of the Society on the National Research Council, F. P. Cullinan, was presented.

The report of the representative of the Society on the Governing Board of the American Institute of Biological Sciences, F. P. Cullinan was also presented.

Reports were then received from Special Committees as follows:

The Committee on Mineral Deficiency Diagnosis was presented and accepted. The contents of this report are given below. The Committee recommended its continuation for the following year and the Society so voted.

Report of the Committee on Post Harvest Physiology was presented. It was suggested that a symposium be held on market diseases and the committee recommended continuance of the policy of placing papers in Post-Harvest Physiology into one group in the Society's program at the Annual Meeting. The Committeee recommended its continuation for another year and the Society so voted.

The report of the Committee on Education was received. It was recommended that the discussion of teaching methods and graduate instruction be continued and that a new aspect, namely, teaching loads, be studied. The committee recommended its continuance for another year and the Society so voted.

The Committee on Rehabilitation of Foreign Libraries presented its report and recommended its continuance for another year. The Society so voted

The Committee on Varieties presented its report which is printed below and recommended that the committee be continued for another year. The Society so voted.

The report of the Committee on Revision of the Constitution Article 3 referring to the qualifications of Active and Associate Members was presented by George Darrow, Chairman. Article III at present reads as follows:

Voting members: Any person who has a baccalaureate degree and holds an official position in any agricultural college, experiment station, or federal or state department of agriculture in the United States or Canada, is eligible to membership. Other applicants may be admitted by vote of the executive committee.

Associate members: Any person not eligible to voting membership will be eligible to associate membership upon vote of the executive committee. Associate members shall not vote and will present papers only at the request of the program committee.

It was suggested by the committee that the wording be changed to read as follows:

Voting members: Any person who has a baccalaureate degree and holds an official position in any agricultural college, experiment station, federal or state department of agriculture, or any other recognized research or educational institution of college level in the United States or Canada is eligible for voting membership. For the purpose of interpretation only such institutions will be considered which allow full freedom in the publication and discussion of results. Other applicants may be admitted by vote of the executive committee.

Associate members: Any person not eligible for voting membership will be eligible for associate membership upon approval by the executive committee but otherwise shall have the same privileges as voting members.

The Society voted to submit the proposed changes in Article III of the Constitution to the Society at its next annual meeting as provided for in Article VI of said Constitution.

The Nominating Committee presented its list of proposed officers for the year 1948–49 and the report was accepted.

FREEMAN S. HOWLETT, *Secretary-Treasurer*

THE LEONARD H VAUGHAN MEMORIAL RESEARCH AWARDS

The Leonard H. Vaughan Memorial Research Awards in Horticulture for papers appearing in Volumes 49 and 50 (Year 1947) of the PROCEEDINGS are as follows:

In Floriculture to Dr. S. L. Emsweller, of the Bureau of Plant Industry, U. S Department of Agriculture, Beltsville, Maryland, for his contribution entitled "The Utilization of Induced Polyploidy in Easter Lily Breeding". Proc. Amer. Soc. Hort. Sci. 49: 379-384. 1947.

In Vegetable Crops to Dr. Oved Shifriss, of the W. Atlee Burpee Company, Doylestown, Pennsylvania, for his contribution entitled "Development Reversal of Dominance in Cucurbita Pepo". Proc. Amer. Soc. Hort. Sci. 50: 330–346. 1947.

WARREN P. TUFTS, *Chairman*
W. B. MACK
G. F. POTTER
H. B. TUKEY
J. E. KNOTT

REPORT OF THE EDITORIAL COMMITTEE

The Editorial Committee is functioning for the first time under a revised directive adopted as a by-law at our Boston meeting. The separation of the duties of the Secretary-Treasurer from those of the Editor-Business Manager was a part of this plan. Briefly, this committee is charged with three duties: first, to establish editorial policy; second, to determine the suitability of papers, under this policy, for publication in the PROCEEDINGS; and third, to appoint an Editor-Business Manager. With regard to the last named duty, the committee feels that it has been very fortunate in securing the best qualified man in the Society.

The remainder of the report deals with the thinking of the committee in regard to editorial policy. We base the remarks upon three questions drawn up by Dr. Tukey for the consideration of reviewers of manuscripts. It is upon these three points that papers submitted for publication are most often questioned by reviewers:

I. Were the technical and experimental methods used adequate to yield accurate and reliable data? As can be readily seen this question penetrates to the organization of the experiment being reported. Obviously an unscientifically planned piece of research cannot result in a scientifically plausible report. It is equally obvious that the purpose of our "Society for Horticultural *Science*" can best be served by procedures and reporting that can be accepted as scientifically sound.

II. Are there any errors of fact, interpretation, or calculation? We have noticed in reviewing papers that those using the standard methods of statistical analysis, and have been presented logically and clearly receive only praise from the reviewer, whether a member of our committee or not. We do feel that the data should be presented in such a way that the reader is in a position to form his own opinion as to the validity of the conclusions drawn.

III. Has the work been carried far enough to warrant publication? The answer to this question is to a large extent a matter of judgment and this is perhaps the most frequent bone of contention between reviewer and author. It even appears to the committee at times that some members of our Society feel that the PROCEEDINGS should encompass reports of the research activities of all members during the preceding year irrespective of scientific merit.

Now it should be emphasized at this point that the committee has no intention of curbing authors just because their opinions differ from those commonly accepted. We do feel, however, that scientific procedure has reached a point where reasonable standards can be accepted. And in general we are inclined to give the author the benefit of the doubt.

Aside from these considerations we have been faced with a problem that we feel should be brought to your attention and to the attention of the Executive Committee. This has to do with the publication of "invitation" papers. Programs both at our national and at our regional meetings include papers by non-members, often as the result of the organization of symposia. We do not feel that our Society is obliged to publish these papers irrespective of their length, organization, or value to the Society as a whole. We believe that every paper should stand on its own merits regardless of its source.

The committee recognizes the desire and need of our members for a useful PROCEEDINGS, and wishes to proceed toward that end without undue hardship on any one having something worth while to report.

S. H. YARNELL, *Chairman*
O. W. DAVIDSON
H. M. MUNGER
K. C. BARRONS
F. S. HOWLETT

REPORT OF THE COMMITTEE ON RESOLUTIONS

The American Society for Horticultural Science is very grateful to the Convention Bureau of Cincinnati and the Hotel Gibson and to the Ohio committee on arrangements, F. S. Howlett, *Chairman,* Alex Laurie, Wesley Judkins, and E. K. Alban, for planning facilities which have so well served the purposes of this meeting.

Special thanks are accorded to the Federated Garden Clubs of Cincinnati, Mrs. Frank E. Garry, *President,* for the delightful tour which was arranged for the ladies attending our meeting.

We appreciate the fine cooperation of the American Society of Plant Physiologists which has so helpfully contributed to the program.

Thanks are extended to officers and committeemen for faithful and efficient conduct of the affairs of the Society.

PAUL WORK, *Chairman*
W. W. ALDRICH

REPORT OF THE COMMITTEE ON JUNIOR BRANCH MEMBERSHIPS

Two new Junior Branch members have been added to the list since the last meeting. These are Washington State and Tennessee.

The committee plans to prepare a folder in the near future which will be sent to all colleges having horticultural groups and this will be sent as early in the school year as possible.

In some institutions horticultural students are organized in optional groups rather than in one Horticultural society. It is urged that such groups take out a joint branch membership or each group might take a membership if that would be more desirable. Programs should be planned so as to meet the qualifications of an organization of this type.

According to the constitution of the Society, each Junior Branch is expected to submit a report of its activities for the year to the secretary, Dr. Freeman S. Howlett, Wooster, Ohio.

Junior branch members desiring to get their collection of the volumes of the PROCEEDINGS started may do so by joining the Society as associate members and then changing to active members as soon as they complete their Bachelor's degree.

EDW. C. STAIR, *Chairman*

REPORT OF THE COMMITTEE ON MINERAL DEFICIENCY DIAGNOSIS

A round table on the subject "Tissue Analysis in Diagnosis of Nutritional Troubles" was held during the Cincinnati meetings with approximately 75 in attendance. The discussion was led by Walter Reuther, E. M. Emmert, and O. W. Davidson with N. W. Stuart as chairman. The interest in this round table and comments on it were favorable.

The chairman of the committee has represented the society at the request of our president in organization of a symposium on mineral nutrition of plants which will be held in Madison, Wisconsin, on August 25 to 27, 1949. Other organizations sponsoring this symposium are the American Society of Plant Physiologists, the Botanical Society of America, the American Society of Agronomy, the Soil Science Society of America, the American Chemical Society and the National Fertilizer Association. Because of the imminent publication of a series of books entitled Reviews in Plant Nutrition, which will include reviews on horticultural crops, the committee decided that it is not desirable at this time to initiate additional literature reviews or compilations of data on mineral nutrition.

Since there are further responsibilities in connection with the symposium to be held at Madison, and since the next meeting of the society will be held in conjunction with meetings of the Soil Science society, and the American Society of Agronomy, the committee recommends that its functions be continued for another year, with appointment of new personnel to be made by our incoming president. It also recommends that a half-day joint session be held with the other societies at Milwaukee on a phase of the subject of mineral deficiency diagnosis.

DAMON BOYNTON, *Chairman*
E. M. EMMERT
N. W. STUART

REPORT OF THE COMMITTEE ON VARIETIES

The following recommendations are made to the General Business Session.

I. That the committee be continued with authority to enlist the services of additional Society members to advise with regard to special horticultural crops. The committee is to be charged with the following duties:

A. To explore further the existing agencies or facilities now available to deal with:

(1) The validation of varietal names of horticultural plants.

(2) The recording of such names and the maintaining of a permanent file of names and descriptions of such varieties.

(3) The preparation and storage in a permanent archive adequate herbarium specimens, photographs and other descriptive material needed in identifying varieties. To this end, the committee is asked to prepare specimen sets of such material illustrating what is considered adequate for variety identification. These are to include examples of fruits, vegetables and ornamentals.

B. To draw up a definite plan for the use of existing agencies and the setting up of such additional facilities as are needed to cover the aspects of the variety problem indicated under A (1), (2), (3).

NOTE: It is recognized that a comprehensive and adequate organization to accomplish these objectives is too great an undertaking to put into immediate operation and that recommendations for immediate fulfilment must be limited to what is practicable. Any plan drawn up will be submitted to the membership for discussion and adoption at the annual meeting of the Society in October, 1949.

II. It is further recommended that the Society ask the American Association of Nurserymen to include varieties of fruits and nuts in their listings of new introductions in the American Nurserymen.

L. H. MacDaniels, *Chairman*
Reid Brooks
V. R. Boswell
Stanley Johnston
J. H. Weinberger

REPORT OF THE COMMITTEE ON REHABILITATION OF FOREIGN LIBRARIES

Your committee on rehabilitation for foreign libraries was appointed to explore the possibility of our Society helping to replace war-lost horticultural literature by opening the way for our members to contribute sets of the Proceedings and other material. Smithsonian Institute offers a service for transportation from Washington of such material.

In the Society News Letter No 2 of May 20, 1948, the appointment of this committee was announced and communications were asked (1) as to libraries that stand in need of replacements and (2) as to sets of the Proceedings of the American Society for Horticultural Science or other material that owners might be willing to contribute. Response on the first point has been almost negligible and on the second it has been nil

This would suggest either that the needs are not widespread or that the persons who should be interested are too fully occupied with more urgent tasks.

Your committee believes our members should know of this service so that sets no longer needed may be placed where they are useful. We would also recommend that members make plans for future disposal of sets, at least to avoid their being discarded as junk, which sometimes happens.

Your committee remains ready to serve in this field and recommends continuance for one year. It is not disposed to press the matter unless more interest is manifested than has hitherto been the case.

Paul Work, *Chairman*
F. P. Cullinan
E. P. Christopher

REPORT OF COMMITTEE ON POST HARVEST PHYSIOLOGY

The committee has prepared a mineographed list of projects on problems relating to post-harvest physiology as reported by the State Experiment Station and Federal groups. This mimeograph prepared by Dr. R. L. Carolus from information submitted by research workers in this field is ready for distribution.

The grouping this year of papers relating to post-harvest physiology in one session by the program committee proved highly desirable.

The round table discussion on the subject of Physiological aspects of Consumer Packaging of Fresh Fruits and Vegetables held during the evening of September 8, was attended by about 30 investigators interested in this field of study.

The committee recommends:

1. That the practice begun this year in devoting a session to papers relating to post-harvest physiology of fruits, vegetables and flowers be continued.
2. That a round table discussion be scheduled on this subject at the next meeting.
3. That a committee be continued to further promote interest in this field.

L. L. CLAYPOOL, *Chairman*
R. L. CAROLUS
ALEX LAURIE
L. L. MORRIS
R. A. SCHROEDER
L. E. SCOTT
EDWIN SMITH
R. M SMOCK
H. C. THOMPSON

MEETING OF THE GREAT PLAINS REGION OF THE AMERICAN SOCIETY FOR HORTICULTURAL SCIENCE, CHEYENNE, WYOMING, AUGUST 12–14, 1948

The Great Plains Region of the American Society for Horticultural Science held its annual meeting August 12–14 at Cheyenne, Wyoming. The Cheyenne Horticultural Field Station of the United States Department of Agriculture was host to the group. Formal sessions were held at the Plains Hotel, and two field tours were made to the experimental plots of the Cheyenne Horticultural Field Station. Refreshments, served to the group by the ladies of the Horticultural Station after a field tour, and an afternoon tea on August 13 for the visiting ladies constituted the social activities of the meetings.

The closing business session following the program was presided over by Vice President McCrory.

The report of the Steering Committee presented by Chairman W. H. Alderman included a number of recommendations and suggestions for the future welfare of the Section. Recommendations that seemed to require action by the group were put in the form of motions and voted on separately. One recommendation was in the form of a resolution:

1. The next annual meeting: It was recommended that the Plains Section accept the invitation of Dr. M. B. Davis to hold the 1949 meeting at Ottawa. Professor Alderman moved that this recommendation be accepted. Mr. Leslie seconded the motion. Carried unanimously.

It was further recommended:

(a) That in view of the large amount of horticultural plant material at Ottawa that the formal part of the program be restricted to allow more time for field observation.

(b) That the formal part of the program be confined to plant nutrition and root stocks in view of the extensive work done on these subjects by Dr. Davis and his associates.

(c) That the meetings be restricted so as not to spread over too much territory geographically.

(d) That the group spend not less than three meeting days at Ottawa with side-trips to other institutions left to individuals or groups in attendance.

(e) That it may be desirable to divide the groups according to subject matter for some of the field tours.

2. Publication of papers: The committee emphasized that the PROCEEDINGS of the American Society for Horticultural Science are available for the publication of papers presented by American Society for Horticultural Science members at regional meetings and that hitherto members of the Plains Section had not taken advantage of this opportunity to the extent that is desirable. It recommended that at the discretion of the authors the papers be submitted to the editor for publication in the Society PROCEEDINGS.
3. The committee deplored the lack of satisfactory records of early meetings, due to the informality of our organization. In view of this deficiency and of the fact that this is the oldest section of the American Society for Horticultural Science it was recommended that a historian be appointed to prepare a Plains Section history and to submit it for publication in the PROCEEDINGS of the Society. Professor Alderman moved that Mr. W. P. Baird be named historian; seconded by Professor Andersen, motion carried.
4. Plant Introductions: Whereas there is a distinct need to bring into the Great Plains of the United States and Canada certain ornamental and fruit plants which are known to exist in the Scandinavian peninsula and other northern areas of Europe, and whereas these are now growing in an area where their hardiness is well established, and whereas these desirable plants are not now available in Canada and the United States:

   Therefore, be it resolved that the Northern Great Plains Region of the American Society for Horticultural Science in session at Cheyenne, Wyoming, August 12–14, 1948, recommend to their respective governmental agencies charged with the business of plant introduction that suitable steps be taken to bring into these countries these valuable plants so that they may be made available for use in Continental North America.

   A list of suggested desirable plants is here appended together with their sources in the cold sections of Europe.

   Rosa canina from Northern Sweden

   Sorbus aucuparia from Northern Sweden

   Hybrids of *Populus tremuloides* from the tree breeding station at Ekebo in Sweden and the Royal College of Agriculture at Upsala, Sweden.

   Quercus robur and *Acer platanoides* from their northern limits near Upsala (could be secured through the Royal College of Agriculture at Upsala).

   Clematis viticella sanguinea grandiflora from the Botanical Garden at Stockholm, Sweden.

   Prunus avium from northern range in Sweden, Norway, and Finland.

   Elcagnus augustifolia from Finland and Poland.

   Juniper communis, upright forms from northern limits (quite common around Upsala, Sweden).

   Moved by Professor Alderman and seconded by Dr. McCrory that the resolution be adopted. Mr. A. F. Dodge of Plant Exploration and Introduction, United States Department of Agriculture, indicated the pleasure and the support of his Division in this movement. Motion carried.

   The report of the Nominating Committee presented by *Chairman* Cram proposed the following officers for 1949: *President*, LeRoy Powers, Cheyenne, Wyoming; *Vice President*, E. T. Andersen, Winnipeg, Manitoba; and *Secretary*, M. B. Davis, Ottawa, Ontario.

A. C. HILDRETH, *Secretary*

The Determination of Calcium and Magnesium in Leaves Using Flame Methods and a Quartz Spectrophotometer

By J. G. Brown, Omund Lilleland, and R. K. Jackson,
University of California, Davis, Calif.

In an earlier paper (1) the authors reported on the use of a Flame Photometer for the determination of potassium and sodium in plant material. The flame used was relatively cool, the temperature being suitable for producing good potassium and sodium spectra, yet low enough to produce minimum emission from other elements in the sample. Under such conditions glass filters could be used to separate the two spectra. Although it has been shown (2) that the presence of other ions in the sample may appreciably raise or depress the intensity of the desired spectra, the authors were able to avoid errors greater than approximately 5 per cent by using quite dilute ash solutions.

Using the hotter air-acetylene flame in conjunction with a spectrograph and photographic plate Lundegardh (3) was able to detect 34 elements. Others (4, 5) using similar equipment were able to quantitatively determine at least eight elements in biological material. When phototubes are used to measure the line intensity, it is probably not possible to determine more than a few elements, unless extremely elaborate equipment is used.

In our present work a Beckman Quartz Spectrophotometer and a flame attachment manufactured by the National Technical Laboratories was used. In this apparatus the solution to be analyzed is injected into an oxygen-natural gas flame. Light from the flame enters the entrance slit of the spectrophotometer, is dispersed into its spectrum by the prism and the desired wavelength is thrown upon a photocell which measures its intensity.

Although this instrument has the advantage of good dispersion and narrow slit widths can be used, concentrations of ions, other than the one being determined, in the sample solution have noticeable effects upon the intensity (photometer reading) of the element being determined. Calcium is more affected in this way than is magnesium. Sodium in particular greatly influences the photometer reading of the calcium lines. This sodium effect can be reduced more than 50 per cent by inserting a didynium glass filter in the photometer's light path.[1]

Fig. 1 shows the effect of some ions commonly present in plant ash solutions upon a standard solution containing 10 p p m of calcium. Portrayal at this calcium concentration is used because the total error produced is larger at low calcium concentrations. For example, the presence of 25 p p m of sodium increases the apparent calcium concentration from 10 to 11 p p m, (10 per cent) while if the true calcium concentration is 80 p p m, the same amount of sodium increases the apparent calcium concentration to only 83 p p m (3.7 per cent).

Since flame photometry is based on the comparison of the photometer reading of the unknown solution with that of a known standard,

[1]This filter was suggested by the National Technical Laboratories.

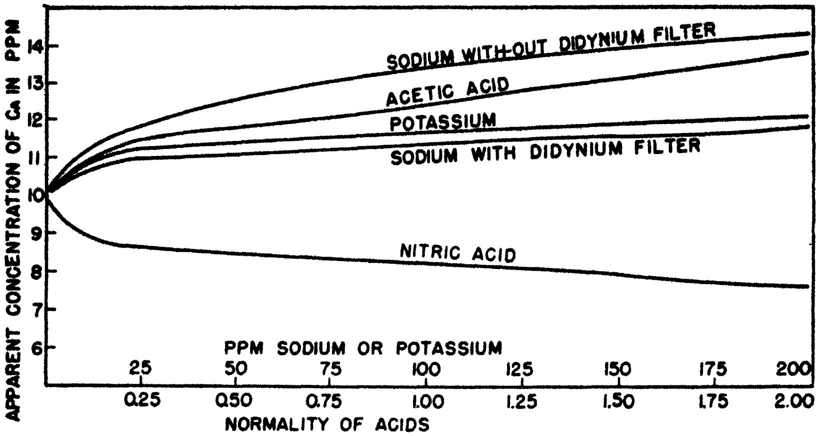

FIG. 1. Effect of certain ions upon the apparent calcium concentration of a standard solution containing 10 p p m of calcium when it is analyzed photometrically.

it is evident from Fig. 1 that the standard must be similar in composition to the unknown. However, the rate of interference rises rapidly with the first few parts per million of interfering substance and then increases slowly thereafter. Consequently, if the standard solution contains only a few parts per million of the interfering ions, it can be used for comparing with unknown solutions which may vary considerably in the amount of interfering ions present. The standard solutions which we used were designed to contain ions in about the same proportions as an average California deciduous leaf sample. They were made up as follows:

The highest magnesium standard consisted of 0.3 normal nitric acid containing, 300 p p m magnesium, 200 p p m calcium, 200 p p m potassium, and 50 p p m sodium. The intermediate standards were of similar composition except the magnesium content was reduced to 225, 150, and 75 p p m magnesium. Using a wave length of 371 millimicrons and a slit width of .26 mm the standard curve obtained from these standards was a straight line ranging from a reading of 75 on the photometer scale (zero magnesium) to 103 divisions on the scale (300 p p m magnesium).

The highest calcium standard used was a 0.03 normal nitric acid solution containing 80 p p m calcium, 20 p p m magnesium, 20 p p m potassium and 5 p p m sodium. The intermediate standards were of similar composition except the calcium was reduced to 60, 40 and 20 p p m calcium. With the didynium filter in the photometer, a wave length setting of 626 millicrons and a slit width of .32 mm the curve obtained from these standards was a straight line ranging from 4 on the photometer scale (zero calcium) to 100 on the scale (80 p p m calcium).

When the photometer is properly adjusted both the magnesium and calcium curves are reproducible and constant from day to day.

Our analytical procedure for determining calcium and magnesium photometrically was as follows: One gram of dried and ground leaf material was ashed in a silica crucible for approximately 2 hours at 550 degrees C in an electric muffle. The soluble ash was taken up with 20 cc of dilute nitric acid by heating to near boiling on a hot plate. The contents of the crucible were transferred to a 100 cc volumetric flask, made up to volume, shaken, and filtered through paper. The amount of nitric acid used was such that the final solution was approximately 0.3 normal.

To determine magnesium photometrically this leaf ash solution was sprayed directly into the flame without dilution after the photometer has been adjusted for magnesium. The amount of magnesium in the solution was obtained by comparing its photometer reading to the standard magnesium curve.

Calcium was similarly determined except the ash solution was diluted ten times (10 cc to 100 cc) before spraying into the flame and the photometer adjusted for calcium.

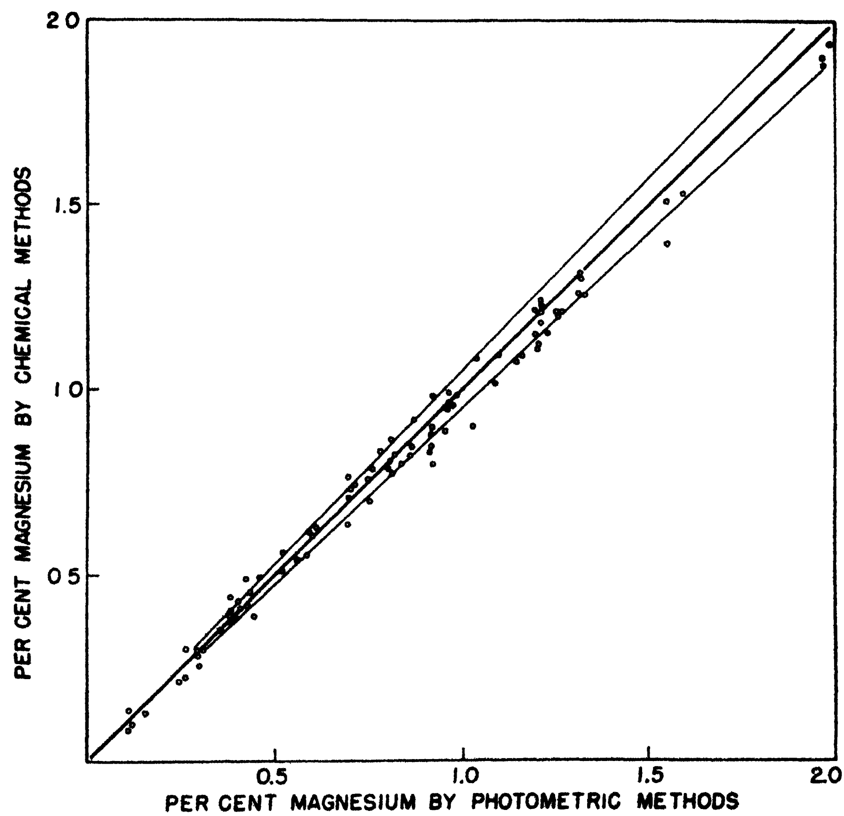

Fig. 2. Comparison between the amount of magnesium found in plant material by chemical and photometric methods. Points between the central and outside lines represent less than 5 per cent difference.

When samples were analyzed routinely with the photometer, distilled water was fed into the photometer after each sample, to be certain the zero setting of the instrument had not drifted. If necessary the zero setting was adjusted. This drifting is troublesome, but an analysis including checking the zero point can be made in 2 minutes.

The accuracy of the photometric method was ascertained by analyzing a number of leaf samples for calcium and magnesium photometrically and chemically and comparing the results obtained by the two methods. Calcium was determined chemically by precipitation as the oxalate and titration with permanganate. Magnesium was determined on the filtrate from the calcium oxalate precipitate by precipitation with sodium ammonium phosphate and titration with sulphuric acid.

The comparative results of the two methods of analysis are shown graphically in Figs. 2 and 3. As shown in Fig. 2 the per cent error of the photometric method for magnesium may become large when the leaf samples contain less than 0.5 per cent magnesium. This is because

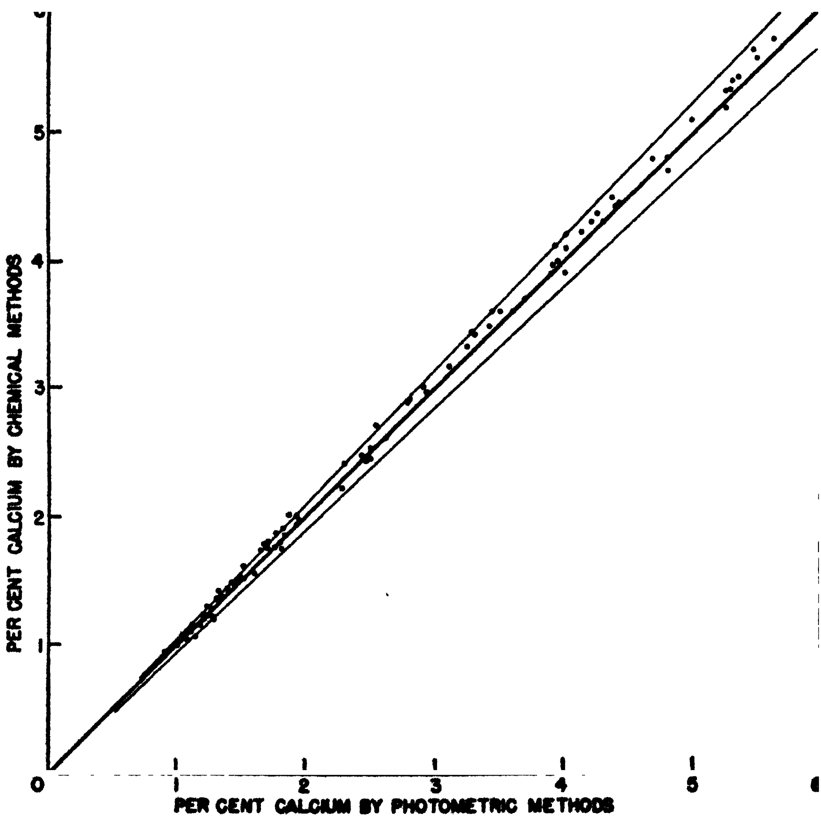

FIG. 3. Comparison between the amount of calcium found in plant material by chemical and photometric methods. Points between the central and outer lines represent less than 5 per cent difference.

the 1-gram sample specified in our outlined procedure does not provide sufficient magnesium in the leaf ash solution. By substitution a 4-gram sample for the 1-gram sample mentioned in our procedure, we find that leaves containing less than 0.5 per cent magnesium can be accurately analyzed for magnesium. Since the dried leaves of California deciduous fruit trees seldom contain less than 0.5 per cent magnesium we prefer the 1-gram sample.

Statistical analysis of 50 calcium comparisons showed the standard deviation of the photometric method from the chemical method to be 2.9 ± 2.08 per cent. Similar analysis of 50 magnesium comparisons, all of which contained more than 0.5 per cent magnesium showed the standard deviation of the photometric method from the chemical method to be 3.8 ± 2.9 per cent.

To permit a more accurate evaluation of the photometric method for calcium and magnesium some of the individual date of Figs. 2 and 3 are presented in Table I.

TABLE I—Comparison Between the Amount of Calcium and Magnesium Found in Plant Materials by Photometric and Chemical Methods

Per Cent Calcium		Per Cent Magnesium		Per Cent Calcium		Per Cent Magnesium	
By the Photometric Method	By the Chemical Method	By the Photometric Method	By the Chemical Method	By the Photometric Method	By the Chemical Method	By the Photometric Method	By the Chemical Method
1.00	1.00	0.08*	0.12	3.52	3.34	0.70	0.75
0.96	0.91	0.10	0.12	3.63	3.64	0.74	0.71
1.20	1.20	0.13	0 13	3.44	3.26	0.73	0.75
1.11	1.10	0.14	0.12	5.20	5.25	0.76	0.75
1.78	1.80	0.22	0.25	3.48	3.42	0.79	0.78
1.44	1.38	0.29	0.28	3.15	3.10	0.84	0.78
1.58	1.63	0.30	0.31	3.92	3.83	0.86	0.81
1.08	1.15	0.37	0.38	3.94	3.79	0.93	0.87
1.75	1.83	0.41	0.39	3.34	3.26	0.95	0.96
1.97	1.93	0 41	0.48	5.44	5.33	0.99	0.96
1.19	1.22	0.49	0.46	3.98	3.92	1.13	1.10
1.74	1.70	0.48	0.55	5.43	5.36	1.15	1.20
1.28	1.32	0.52	0.53	5.22	5.28	1.21	1.28
1.48	1.45	0.56	0.54	2.43	2.28	1.38	1.52
1.32	1.28	0.54	0.58	4.15	3.92	2.00	2.07

*All photometric analysis were made using 1-gram samples according to our outlined procedure.

Inasmuchas the amount of potassium, sodium, or chloride in the leaf could affect the accuracy of the photometric method, we selected leaf samples containing varying amounts of these "interfering ions" and analyzed them photometrically and chemically. The result of these analysis are shown in Table II. From the data in this table it is evident that the photometric method is accurate and not influenced by the varying composition of the leaf material.

The principal advantage of the photometric method over the chemical method is its greater speed. Starting from the leaf ash solution we find it takes about 20 minutes to determine calcium and magnesium chemically. Approximately 4 minutes are required to do these analyses photometrically. About the same degree of technical skill is required for either method.

TABLE II—THE EFFECT OF VARIOUS AMOUNTS OF POTASSIUM, SODIUM AND CHLORIDE UPON THE PHOTOMETRIC DETERMINATION OF CALCIUM AND MAGNESIUM IN LEAF MATERIAL EXPRESSED IN PER CENT DRY WEIGHT*

No.	Calcium		Magnesium		Potassium	Sodium	Chloride
	By the Photometric Method	By the Chemical Method	By the Photometric Method	By the Chemical Method			
1	2.28	2.28	1.45	1.56	0.30	0.03	0.04
2	1.89	1.78	0.54	0.57	0.97	0.04	0.18
3	5.13	4.96	2.80	2.83	0.18	0.07	0.06
4	1.43	1.47	0.27	0.26	0.40	0.02	0.01
5	1.15	1.16	0.21	0.23	0.55	0.03	0.01
6	1.78	1.65	0.71	0.70	1.55	0.04	0.24
7	2.01	1.94	0.93	0.93	1.70	0.04	0.20
8	1.94	1.94	0.84	0.82	1.69	0.04	0.24
9	1.78	1.78	0.85	0.87	1.58	0.06	0.18
10	2.60	2.60	0.89	0.95	3.87	0.05	0.15
11	4.30	4.20	1.23	1.22	0.35	0.55	1.48
12	4.13	4.00	1.33	1.33	0.45	1.26	0.58
13	3.62	3.42	1.32	1.33	0.30	1.76	0.68
14	4.70	4 80	1.54	1.60	0.30	1.40	1.08
15	4.78	4.81	1.51	1.55	0.46	1.14	0.88
16	4.28	4.00	1.26	1.21	1.31	0.12	0.78
17	4.30	4.31	1.21	1.20	0.42	0.27	0.56
18	4.00	3.95	1.02	1.16	0 37	0 16	0.42
19	4.23	4.12	1.24	1.22	0.33	0.14	0.58
20	4.42	4.39	1.22	1.22	0.83	0.14	0.54

*Numbers 1–5 low K, Na and Cl, numbers 6–10 high K, low Na and Cl, numbers 11–15 low K, high Na, and Cl, numbers 16–20 low K, low Na, high Cl.

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Potassium, Calcium, and Magnesium Content in Citrus Flowers Collected from Trees on Various Rootstocks

By A. R. C. Haas, *University of California Citrus Experiment Station, Riverside, Calif.*

It was pointed out in a previous report (2) that the total phosphorus content in the dry matter of Eureka lemon and Valencia orange flowers collected from trees grown with the same scion variety and soil conditions is related to the nature of the rootstock variety. It is desirable to learn whether or not the concentration of other inorganic constituents such as potassium, calcium, and magnesium in these flowers bears any relation to the rootstock variety.

For any one variety, all of the trees are of the same age and the scion buds came from a single tree. The scion origin and the care taken in the selection of the rootstocks have been described in detail by Webber (3). The rootstock plots each consist of five trees and occur in duplicate, the general plan of the rootstock plots having been described by Batchelor and Webber (1).

The entire flowers including the pedicel were collected without the loss of any of the petals. Only the freshly opened and fully expanded flowers were included in the sampling. A collection was made of Eureka lemon flowers from trees in field 3 on December 10, 1946 and a second collection was made on October 20, 1947. A single collection was made of Valencia orange flowers on April 17, 1945 from trees in field S1A. Both fields are located at the Citrus Experiment Station at Riverside and receive a uniform fertilizer treatment.

Samples each consisting of several hundred flowers were dried at 65 degrees C in a well ventilated oven. After being ground in a micro Wiley mill, the samples were placed in envelopes made by folding heavy brown paper and these were inserted into heavy brown paper bags bearing the desired information regarding the sample. The samples were then stored in an oven maintained at 50 degrees C until duplicate aliquots were weighed.

A small quantity (0.25 ml) of concentrated H_2SO_4 diluted in 10 ml distilled water was added to the moistened dry matter prior to the ashing at low temperature in the determination of potassium. The ash insoluble in hot water plus the filter paper were dried and ashed again in the same dish. The dilute HCl solution was evaporated to dryness in a beaker and gently ignited prior to the lengthy and accurate procedure for determining potassium as the chloroplatinate.

In other aliquots the dry matter was ashed at low temperature in the determination of calcium and magnesium. The salts soluble in hot water were removed from the cool ash. The insoluble ash and the filter paper were dried and ashed again in the same dish until entirely white. From the heated dilute HCl solution, calcium was twice precipitated as the oxalate and the titration was made with permanganate. Magnesium was precipitated as the phosphate and was weighed as the pyrophosphate.

The results obtained were arranged in descending order of magni-

tude in order to reveal any relation of the values to the roostock variety. The data for potassium in Eureka lemon flowers collected on December 10, 1946 are shown in Table I. The values for potassium

TABLE I—Potassium Content of Eureka Lemon Flowers Collected December 10, 1946 from Trees on Various Rootstocks in Field 3 at the Citrus Experiment Station, Riverside

Rootstock Variety	Location in Orchard			Potassium (Per Cent in Dry Matter)
	Block	Row	Trees	
C. E. S. No. 343 Grapefruit	B	21	1–5	1.806
C. E. S. No. 343 Grapefruit	B	36	6–10	1.750
Rubidoux Sour Orange	C	11	1–5	1.730
Duncan Grapefruit	B	23	1–5	1.722
Sampson Tangelo	B	38	6–10	1.688
Rubidoux Sour Orange	B	29	1–5	1.666
Bessie Sweet Orange	B	10	1–5	1.630
Sampson Tangelo	C	23	11 15	1.584
Bessie Sweet Orange	C	12	1–5	1.557
Brazilian Sour Orange	B	28	1–5	1.525
Cleopatra Mandarin	B	35	6–10	1.511
Madam Vinous Sweet Orange	C	13	1–5	1.498
Cleopatra Mandarin	C	13	6–10	1.473
Madam Vinous Sweet Orange	B	28	6–10	1.461
Rough Lemon	B	26	1-5	1.376
Brazilian Sour Orange	C	15	1–5	1.302
Sweet Lemon	C	17	6–10	1 163

ranged from 1.163 per cent for Sweet lemon rootstock to 1.806 per cent for C.E.S. No. 343 grapefruit rootstock. Grapefruit, Tangelo, and Bessie sweet orange rootstocks occur in the upper portion of the list whereas Mandarin, Madam Vinous sweet orange, Rough lemon, and Sweet lemon rootstocks are found in the lower portion of the list.

In the Eureka lemon flower collection of October 20, 1947 (Table II) the grapefruit and Tangelo rootstocks are again high in the list of potassium values, whereas Rough lemon and Sweet lemon rootstocks occur at the bottom of the list. Good agreement of the potassium values was often found for trees on the same rootstock despite the distance of one row of trees from the other in the experimental orchard.

Although the values for calcium and magnesium in lemon flowers are much lower than those for potassium, considerable grouping of similar rootstocks is evident in some cases. In their calcium percentages the grapefruit rootstocks appear to vary markedly. Lemon rootstocks occur high in the list of calcium values, whereas Tangelo and Madam Vinous sweet orange occur low in the list. The grapefruit rootstock occurs low in the list of the magnesium values, whereas lemon and Tangelo rootstocks occur high in the list.

In the Valencia orange flower collection of October 20, 1947 (Table II) Tangelo, grapefruit, and citrange rootstocks occur in the upper portion of the group of potassium values. Shaddock and Mandarin rootstocks occur near the middle, whereas Rough lemon rootstock occurs at the bottom of the list of potassium values. There is considerable resemblance in the potassium positions of the rootstocks of trees from which the Eureka lemon and Valencia orange flowers were obtained.

TABLE II—INORGANIC COMPOSITION OF EUREKA LEMON AND VALENCIA ORANGE FLOWERS FROM TREES ON VARIOUS ROOTSTOCKS

Lemon Flowers From Trees on Various Rootstocks	Location in Orchard: Block and Row	Location in Orchard: Trees	Content in Dry Matter	Valencia Orange Flowers From Trees on Various Rootstocks	Location in Orchard: Row	Location in Orchard: Trees	Content in Dry Matter
Potassium (Per Cent in Dry Matter)							
Sampson Tangelo	B38	6–10	1.940	Sampson Tangelo	31	6–10	1.836
Duncan Grapefruit	B23	1–5	1.892	C.E.S. No. 343 Grapefruit	33	1–5	1.765
C.E.S. No. 343 Grapefruit	B36	6–10	1.863	Savage Citrange	23	6–10	1.735
Sampson Tangelo	C23	11–15	1.821	C.E.S. No. 343 Grapefruit	36	11–15	1.670
C.E.S. No. 343 Grapefruit	B21	1–5	1.807	Koethen Sweet Orange	35	1–5	1.657
Brazilian Sour Orange	B28	1–5	1.789	Siamese Shaddock	32	1–5	1.626
Madam Vinous Sweet Orange	C13	1–5	1.772	Siamese Shaddock	35	11–15	1.603
Madam Vinous Sweet Orange	B28	6–10	1.767	Cleopatra Mandarin	32	11–15	1.577
Brazilian Sour Orange	C15	1–5	1.704	Cleopatra Mandarin	31	11–15	1.538
Rubidoux Sour Orange	B29	1–5	1.644	Koethen Sweet Orange	28	6–10	1.526
Cleopatra Mandarin	B35	6–10	1.638	African Sour Orange	27	1–5	1.367
Rough Lemon	B26	1–5	1.574	Rough Lemon	32	6–10	1.274
Rough Lemon	C14	1–5	1.499	Rough Lemon	30	1–5	1.181
Sweet Lemon	C17	6–10	1.321				
Calcium (Per Cent in Dry Matter)							
Rough Lemon	C14	1–5	0.762	Siamese Shaddock	35	11–15	0.862
Sweet Lemon	C17	6–10	0.729	Savage Citrange	23	6–10	0.841
Duncan Grapefruit	B23	1–5	0.707	African Sour Orange	27	1–5	0.797
Brazilian Sour Orange	B28	1–5	0.704	Siamese Shaddock	32	1–5	0.775
Rough Lemon	B26	1–5	0.699	Sampson Tangelo	31	6–10	0.744
C.E.S. No. 343 Grapefruit	B21	1–5	0.683	Cleopatra Mandarin	32	11–15	0.729
Brazilian Sour Orange	C15	1–5	0.682	C.E.S. No. 343 Grapefruit	36	11–15	0.704
Cleopatra Mandarin	B35	6–10	0.675	C.E.S. No. 343 Grapefruit	33	1–5	0.681
Rubidoux Sour Orange	B29	1–5	0.672	Koethen Sweet Orange	35	1–5	0.672
Sampson Tangelo	C23	11–15	0.646	Rough Lemon	32	6–10	0.655
Sampson Tangelo	B38	6–10	0.630	Rough Lemon	30	1–5	0.635
C.E.S. No. 343 Grapefruit	B36	6–10	0.626	Cleopatra Mandarin	31	11–15	0.633
Madam Vinous Sweet Orange	C13	1–5	0.620	Koethen Sweet Orange	28	6–10	0.622
Madam Vinous Sweet Orange	B28	6–10	0.608				
Magnesium (Per Cent in Dry Matter)							
Rough Lemon	B26	1–5	0.218	Savage Citrange	23	6–10	0.210
Brazilian Sour Orange	C15	1–5	0.215	Sampson Tangelo	31	6–10	0.209
Sampson Tangelo	C23	11–15	0.212	Siamese Shaddock	35	11–15	0.205
Rough Lemon	C14	1–5	0.210	Siamese Shaddock	32	1–5	0.201
Sweet Lemon	C17	6–10	0.206	C.E.S. No. 343 Grapefruit	33	1–5	0.200
Sampson Tangelo	B38	6–10	0.205	Cleopatra Mandarin	31	11–15	0.199
Brazilian Sour Orange	B28	1–5	0.204	Rough Lemon	30	1–5	0.184
Madam Vinous Sweet Orange	C13	1–5	0.202	Koethen Sweet Orange	35	1–5	0.184
C.E.S. No. 343 Grapefruit	B21	1–5	0.199	C.E.S. No. 343 Grapefruit	36	11–15	0.181
Cleopatra Mandarin	B35	6–10	0.195	Cleopatra Mandarin	32	11–15	0.180
C.E.S. No. 343 Grapefruit	B36	6–10	0.194	African Sour Orange	27	1–5	0.180
Duncan Grapefruit	B23	1–5	0.193	Rough Lemon	32	6–10	0.175
Madam Vinous Sweet Orange	B28	6–10	0.182	Koethen Sweet Orange	28	6–10	0.167
Rubidoux Sour Orange	B29	1–5	0.178				

Citrange, Tangelo, and Shaddock rootstocks are situated high in the list of calcium and magnesium values for Valencia orange flowers.

SUMMARY

A collection was made of Eureka lemon flowers on December 10, 1946, and a second collection on October 20, 1947, whereas a single collection was made of Valencia orange flowers on April 17, 1945. All flowers were obtained from citrus trees that consisted of similar scions on various rootstocks and grown in an experimental orchard with uniform soil and orchard practices.

The data emphasize the excessive loss of potassium during the flowering period. The first collection of lemon flowers showed a wide range in the percentage of potassium in the dry matter; the lowest value being 1.163 per cent for Sweet lemon rootstock and the highest value 1.806 per cent for C.E.S. No. 343 grapefruit rootstock. Grapefruit, Tangelo, and Bessie sweet orange rootstocks occur in the upper portion of the potassium range, whereas Mandarin, Madam Vinous sweet orange, Rough lemon, and Sweet lemon rootstocks occur in the lower portion of the range.

The second collection of lemon flowers again show grapefruit and Tangelo rootstocks high in the list of potassium values with Rough lemon and Sweet lemon again near the bottom of the list.

Lemon rootstocks occur high in the list of calcium values, whereas those of Tangelo and Madam Vinous sweet orange occur low in the list. Grapefruit rootstock occurs low in the list of magnesium values.

In the dry matter of Valencia orange flowers, the percentages of potassium were highest for Tangelo, grapefruit, and citrange rootstocks and lowest for Rough lemon rootstock. Citrange, Tangelo, and Shaddock rootstocks are high in the list of calcium and magnesium percentages.

The results indicate that the percentages of potassium, calcium, and magnesium found in the dry matter of citrus flowers are associated with the nature of the rootstock variety.

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The Nutrition of Tung Trees

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The commercial culture of tung trees in the United States dates from 1925 and the tung area as now developed covers a belt about 100 miles wide, extending along the Gulf coast from eastern Texas to the Atlantic seaboard and southward into Florida to the region around Gainesville. There are now in commercial plantings about 200,000 acres, of which about 60 per cent is located in the state of Mississippi. An average of about 18 or 19 million pounds of oil, having a market value of between 4 and 5 million dollars, was obtained in 1946 and 1947 from the fruit of these trees. With the expanded acreage and the improved varieties and cultural practices, annual production should increase during the next decade. For some years prior to World War II we consumed on the average each year about 100 million pounds of tung oil from China, which gives one some idea of the gap between production and consumption in this country.

In order to help the infant tung industry, Congress, in 1938, at the request of the tung growers, appropriated funds to be used in research on the various problems confronting the industry. Since then the Bureau of Plant Industry, Soils, and Agricultural Engineering at its four field stations located in the tung belt and at the Plant Industry Station, Beltsville, Maryland, has been working on these problems. The main objective of our work has been to enable the grower to produce more tung oil per acre at a lower cost per pound. During this period numerous technical and popular papers have been published setting forth the results of different phases of these studies.

Some of the results obtained from the nutritional studies carried out are presented here.

As the Federal Government does not own a single acre of tung trees, all the research studies have of necessity been conducted on a cooperative basis with tung growers and State Experiment Stations.

Sand-culture and field experiments, analyses of the soil and of roots, trunks, branches, and leaves of the trees, and a close study of the external leaf symptoms in particular, have been used in investigating the nutritional problems. Foliage analyses and the close study of foliar symptoms have been especially valuable in solving some of the immediate nutritional and deficiency problems confronting the tung industry.

Soils

The tung belt comprises a large area and the soil types found within it are numerous and varied. They range in suitability for tung from the best to the definitely unsuited, and the nutritional problems arising from this fact are accordingly varied.

It has been found that the tung tree, just as the apple and the peach tree, grows and produces best on fertile, well-drained soils. Ruston, Red Bay, Orangeburg, Norfolk, Ora, Arredondo, and Gainesville sandy and fine sandy loams are common soil types upon which much

of the commercial tung acreage is now located and doing well. Tung trees do not thrive on the deep sands or on the poorly drained soils like those of the Leon, Fellowship, and Caddo series.

Roughly speaking the heavier soil types are for the most part to be found in the northern and western parts of the tung belt and the lighter soils mostly in the peninsular Florida area (6). Because of the wide range in the fertility of the soil types to which tung is suited, the fertilizer requirements are widely different and no general over-all single fertilizer formula for tung can be hoped for. In general the heavier soils require less fertilizer and to date have shown less need for the application of the minor elements.

Nitrogen

The tung tree, like the apple or peach, requires a good supply of readily available nitrogen to maintain optimum growth and production. Under the soil and climatic conditions of the tung belt at least yearly nitrogen applications are required. Thorough and frequent cultivation must be given the trees early in the season to prevent weed competition for nutrients and moisture. As with other trees, nitrogen deficiency is characterized by a general yellowing of the foliage, and in severe cases a reddish purple coloring of the petioles also develops. In general tung orchards in the past have not received sufficient nitrogen fertilizer.

It has been learned that nitrogen in the form of ammonium nitrate is just as effective when applied to tung trees in Florida as early as December, January, or February, as when applied in March or April (8).

In one experiment 1 pound of nitrogen (one-third as nitrate of soda; two-thirds as ammonium sulfate) applied to 5-year-old tung trees, increased the yield of oil more than 40 per cent the following year (15). This high level of nitrogen fertilization in this same experiment produced an increase in the number of shoots and also increased by 33 per cent the number of pistillate flowers per shoot. Also the high nitrogen application was found to reduce slightly the percentage of oil in the kernel. However it increased the size of the kernel sufficiently to give a net gain of 1.0 in the percentage of oil in the whole fruit. Essentially the same results have been obtained in other experiments conducted in several different areas of the tung belt.

Phosphorus

The results of experiments over the tung belt until last season made it doubtful that there was a need for applying additional amounts of phosphorus directly to mature tung trees. Response to phosphorus had been obtained only with young trees on severely phosphorus-deficient soils. Results recently obtained in a study by Sitton (16) reveal a very highly significant interaction between nitrogen and phosphorus in their effect on yield. At the low level of nitrogen, applications of phosphorus over and above the amount applied to the cover crop were ineffective, but at the high level of nitrogen the additional phosphorus produced a large increase in yield. In addition to any direct aid to the trees from

applications of phosphorus, cover crops grown in the orchards have been greatly benefited and it is felt that mature tung trees in such orchards will eventually benefit from the increased amount of cover crop produced.

Potassium

In July and August of 1941 the leaves on the trees in large areas in tung orchards of northern Florida, in Georgia, and in Alabama were showing deficiency patterns of such a nature as to seriously affect the normal functioning of the leaves (5). Leaf samples were taken, analyzed, and found to be so much lower in potassium than normal leaves that an experiment was set up to determine if soil applications of potash would correct the disorder.

The treated trees, as judged by the appearance and potassium content of their foliage, made practically full recovery the following season (10).

On the basis of these findings increased potassium fertilization has been recommended and used on tung trees growing on the Red Bay and related soils series in the potash-deficient areas in northern Florida and southern Georgia. Until recently potassium deficiency was not a problem in the large tung areas in Mississippi and Louisiana. However, with increased production of tung fruit as the result of higher nitrogen fertilization and better cultural practice, there has been a considerable drain on the potassium reserves of the soil. This has brought about the need for more attention to the potassium requirements in these areas. In general the potassium content of most soils of the tung belt is quite low, ranging from about 10 to usually less than 70 parts per million of exchangeable potassium.

Repeated field experiments over a period of years on several soil types have demonstrated that increased potassium fertilization increases the amount and oil content of kernel, thereby substantially increasing the percentage of oil in the whole fruit (11). This increase is most marked with high potassium applications to soils low in potassium. In one experiment the oil in the whole fruit was increased more than 15 per cent.

Magnesium

A severe marginal leaf scorch was observed on tung trees in the Gainesville area during the 1940 growing season. As the cause was thought to be a mineral deficiency, several different elements were applied to the ailing trees. From the results of these studies and information gained from foliar analyses the trouble was found to be due to a deficiency of magnesium (4). It was learned that the deficiency could be corrected, even in the case of severely affected trees, in two years' time by applying 4 to 8 pounds of magnesium sulfate to 6- to 10-year-old trees.

Magnesium deficiency was widespread in the tung orchards in northeastern Florida on the very sandy soils and on those poorly drained. The trouble has now been largely eliminated due to the use by the growers of soluble magnesium fertilizer materials either incor-

porated in the mixed fertilizers or used as supplementary applications. Magnesium deficiency, as would be anticipated, seriously decreases production. In one experiment now under way it has been found that trees showing severe foliage symptoms of magnesium deficiency yielded only half so much as trees only slightly affected.

Zinc

The problem of zinc deficiency or "bronzing" was recognized and solved by Florida Agricultural Experiment Station workers soon after the establishment of the tung industry (9). This deficiency has been prevalent in tung orchards growing on most soil types of the tung belt, although it was most prevalent in those on lighter soils in northeastern Florida. It causes malformation of the foliage which develops a bronze coloration with increasing severity of the disorder. Growth of the tree is impaired, and because of this the yield is greatly reduced. This deficiency is usually readily corrected by soil applications of 2 to 4 ounces of zinc sulfate per tree per year according to the age of the tree. For obtaining quick recovery on young trees, an 8–8–100 spray of zinc sulfate and hydrated lime has proven very effective.

Manganese and Iron

Manganese-deficiency symptoms or "frenching" were also recognized and the problem solved early in the history of the tung industry by Florida Agricultural Experiment Station workers (12).

This deficiency is characterized by the appearance early in the season of light green to yellow to almost white chlorotic areas on the leaves, which start near the leaf margin and progress inward between the veins. Necrotic areas appear within the chlorotic areas as the disorder increases in severity. As the season progresses and rains become more frequent in June and later, the severity of the leaf symptoms decreases and, except in very severe cases, will usually disappear. When the deficiency is slight, soil applications of 2 to 4 ounces of manganese sulfate per tree per year will effectively control it, but in severe cases up to 4 pounds per tree may be needed. It is of interest to note that in an experiment with moderately deficient bearing trees, applications of 2 pounds of manganese sulfate per tree per year over a 3-year period have failed to increase the yield of the trees, although correcting the leaf symptoms.

Iron deficiency has also been recognized and corrected by the Florida Agricultural Experiment Station workers (1) by soil and foliage spray applications of iron sulfate. This deficiency was found only in a few orchards and as yet has not proven to be of economic importance.

Copper

In the summer of 1941 a peculiar cupping of the terminal leaves, which were smaller than average, and an interveinal chlorosis were observed in a tung orchard near Morriston, Florida. As it was thought that the trouble was caused by the lack of some minor element, the

problem was attacked the following season from that angle and the disorder was found to be due to a deficiency of copper (3).

Copper deficiency has been observed only in tung orchards in northeastern Florida. Soil applications of ½ to 1 pound of copper sulfate corrected the trouble in 8-year-old trees. One foliage application in the spring of an 8–8–100 copper sulfate and lime spray was found effective in controlling the deficiency on 1- to 4-year-old trees.

Copper deficiency was found to have a profound effect on oil formation. The yield of oil from copper-deficient trees was only two-thirds of the yield from normal trees because of the smaller size of fruit and the lower percentage of oil in them.

Foliar Analysis

It has been previously mentioned that foliar analysis has been very helpful in the diagnosis of mineral-deficiency troubles and in determining the fertilizer requirements of tung trees (2).

From experiments and observations correlated with analyses of several thousand leaf samples, Table I has been compiled as an aid to

TABLE I—Tentative Optimum and Deficiency Ranges in the Percentage of Mineral Elements in Midshoot Tung Leaves Collected in August from Bearing Trees, Dry Basis

	Per Cent Nitrogen	Per Cent Phosphorus	Per Cent Potassium	Per Cent Calcium	Per Cent Magnesium	Zinc (Ppm)	Copper (Ppm)	Manganese (Ppm)
Optimum* ..	2.2–2.5	0.15–0.18	0.80–1.00	1.8–2.5	0.35–0.45	30–50	6–8	75–200
Deficiency**	1.2–1.5	——†	0.40–0.60	——*	0.15–0.20	10–20	3–4	30–50

*Amounts higher than indicated optimum are frequently found without having caused either beneficial or ill effects; for example, manganese at 1,200 to 2,000 ppm. This is known as luxury consumption. On the other hand potassium above 2.5 per cent, nitrogen above 3 per cent, and boron above 125 ppm are known to be associated with reduced growth or toxicity symptoms.

**Deficiency range refers to that at which foliage disorders occur.

†Leaf symptoms of deficiency not known.

more intelligent fertilizer recommendations. This table admittedly has its limitations and will undoubtedly have to be modified from time to time as additional experimental evidence becomes available. It has, however, been useful in a practical way as a guide in correcting mineral-deficiency troubles and in maintaining good levels of fertility in tung orchards. The "optimum" ranges refer to those levels above which there is no evidence of increased growth and production. The "deficiency" range refers to the level at which foliage disorders occur. As is the case with most foliage, nitrogen and calcium are present in greatest concentration, followed by potassium, magnesium, phosphorus, and manganese. It should be noted that phosphorus- and calcium-deficiency symptoms have not been observed, or at least they are not recognized as such.

Nutrient Balance

As a result of the work of others, as well as of our own, it is becoming more and more evident that the total quantity of minerals present in the foliage is only a part of the information needed to help solve

plant-nutrition problems. The balance of the several mineral elements appears of great significance and is now receiving increasing attention (14).

In a number of experiments it has been observed that the potassium-magnesium ratio is a very sensitive one that must be carefully controlled.

In 1946 leaf samples were taken from trees in a fertilizer study. The results indicated that the level of potassium was below normal even in the high-level plots. Therefore, the level was increased from 0.8 pounds of potash per tree in 1946 to 1.6 pounds in 1947. Leaf samples were taken again in August 1947. The magnesium content of these leaf samples as well as the potassium was determined in 1946 and 1947 and the results are shown in Table II.

TABLE II—THE EFFECT OF INCREASED POTASSIUM APPLICATIONS ON THE POTASSIUM AND MAGNESIUM CONTENT OF TUNG LEAVES

Replications of Treatment G*	1946			1947		
	Per Cent K	Per Cent Mg	K**/Mg	Per Cent K	Per Cent Mg	K**/Mg
1	0.73	0.38	0.59	0.95	0.18	1.62
2	0.52	0.68	0.24	0.73	0.44	0.51
3	0.42	0.64	0.20	0.75	0.38	0.61
4	0.67	0.38	0.54	1.03	0.22	1.44

*1946: .5 pound of N, 0.05 pound of P_2O_5, 0.8 pound of K_2O applied per tree. 1947: 1.00 pound of N, 0.20 pound of P_2O_5, 1.6 pounds K_2O applied per tree. And in addition 1.15 pounds of hydrated lime was spread yearly in a 10-foot circle beneath each tree.

**Calculated on an equivalent basis.

It is observed that there is a considerable range in the potassium and magnesium content between replications in both 1946 and 1947. Also it is noted that the heavier application of potassium made in 1947 increased the percentage content of potassium in the foliage by about 0.28.

However, the most interesting fact is that the increased application of potassium in 1947 reduced the magnesium content of the foliage by about 0.21 per cent. This resulted in a marked increase in the potassium-magnesium ratio in each replication. It is thus evident that the competitive effect between potassium and magnesium so often found by others working with different species, also exists in the case of tung. This has been confirmed by experiments carried on during the past few years by associates at the United States Tung Laboratories.

The copper-nitrogen relationships of the tung tree have also been shown to be delicately balanced (7). Table III presents data obtained in such a study. The data show that as the amount of nitrogen applied was increased an increase resulted in the degree of copper-deficiency symptoms on the foliage. Furthermore, they show that as increased quantities of copper were applied the severity of the copper-deficiency symptoms that developed on the foliage was reduced.

The importance of a potasium-nitrogen balance has become evident in field experiments with tung trees in recent years and a paper in press by Painter and others discusses this relationship.

TABLE III—EFFECT OF VARIOUS RELATIVE AMOUNTS OF COPPER AND OF NITROGEN ON SYMPTOMS OF COPPER DEFICIENCY SHOWN BY 1-YEAR-OLD SEEDLING TUNG TREES AT HAGUE, FLORIDA, ON SEPTEMBER 11, 1944

Copper Sulfate Per Tree (Ounces)	Nitrogen Equivalent to Stated Amounts of Nitrate of Soda Per Tree			Average Effects at Copper Levels (Score)*
	1 Ounce (Score)*	9 Ounces (Score)*	18 Ounces (Score)*	
0	5.0	35.0	62.5	42.6
1	5.0	22.5	42.5	23.4
2	0.0	7.5	5.0	4.2
Average effects at nitrogen levels	3.3	21.7	36.7	

*Scoring on basis of 0 = no visible symptoms, to
100 = all branches showing severe symptoms.

SUMMARY AND CONCLUSION

A brief capitulation is presented of the nutritional problems of the tung industry that have been recognized, diagnosed, and in some measure solved.

It is felt that although we have made considerable progress to date toward the solution of the nutritional problems of the tung industry, the future holds even greater promise. The new concepts of nutrition set forth by Shear, Crane, and Myers (14), and the outstanding responses obtained by Roach and his associates (13) from injection and spray applications of minor elements to apparently normal plants, indicate methods of approach that should lead to further progress in solving the problems of maintaining optimum nutritional conditions for tung production as well as for other tree crops.

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Responses of Bearing Tung Trees on Red Bay Fine Sandy Loam to Potassium and Nitrogen

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DURING the summer of 1941 tung trees on Red Bay fine sandy loam in Georgia and Florida showed symptoms of severe potassium deficiency as described by Drosdoff and Painter (1) and by August excessive defoliation had occurred. Preliminary experiments in an orchard near Capps, Florida showed that this condition could be corrected by the application of liberal amounts of potassium salts (3). However, it was thought advisable to set up more extensive tests to determine the level of potassium required, the relative merits of different sources, and the effect of level of nitrogen on the potassium requirement.

MATERIALS AND METHODS

The experiment, which was begun in 1942 in an orchard near Lloyd, Florida, where the potassium deficiency symptoms were most pronounced, consisted of 14 treatments (Table I) replicated six times, with five trees per plot. The check treatment represented the current practice of the cooperator. It had been previously observed by Painter and Potter (4) that a mulch consisting of freshly cut weeds noticeably reduced the severity of potassium deficiency symptoms on trees in a similar orchard, hence treatments B and C were added. Treatment B consisted of a freshly cut winter cover crop of vetch or lupine and treatment C consisted of a freshly cut summer cover crop of crotalaria, both applied as a mulch underneath the spread of the branches of the trees.

TABLE I—TREATMENTS 1944–1946*

Treatment	K_2O Per Tree (Pounds)	N Per Tree (Pounds)	Source of N Material	Source of K Material
A (check)	0.35	0.20	4-10-7 Commercial	4-10-7 Commercial
B	—	—	Hairy vetch mulch (except 1946, blue lupine mulch)**	
C	—	—	Crotalaria mulch	Crotalaria mulch†
D	1.52	0.72	Nitrate of soda	Muriate of potash
E	1.52	0.48	Nitrate of soda	Muriate of potash
F	0.76	0.37	Nitrate of soda	Muriate of potash
G	0.76	0.24	Nitrate of soda	Muriate of potash
H	1.52	0.72	Nitrate of soda	Sulphate of potash
I	1.52	0.48	Nitrate of soda	Sulphate of potash
J	0.76	0.37	Nitrate of soda	Sulphate of potash
K	0.76	0.24	Nitrate of soda	Sulphate of potash
L	1.52	0.72	Potassium nitrate	Potassium nitrate and muriate of potash
M	0.35	0.72	Nitrate of soda and 4-10-7 commercial	4-10-7 commercial
N	1.52	0.20	4-10-7 commercial	Muriate of potash and 4-10-7 commercial

*In 1944-1946 the rates of application of potassium were 15 per cent higher than in 1943, except in treatments A and M which were 20 per cent higher. The rates of application of nitrogen in treatments A and N were 20 per cent and in treatments H and M were 15 per cent higher than in 1943. Treatments D to L inclusive received 2 pounds of 20 per cent superphosphate per tree per year.

**110 pounds per tree in 1943; 150, 1944; 200, 1945 and 1946.

†150 pounds per tree in 1944; 200, 1945 and 1946.

The preliminary experiment at Capps had indicated that the balance between potassium and nitrogen is important; and therefore eight treatments (D to K inclusive) consisted of the factorial combinations of two levels of potassium, each from two sources, with two N/K_2O ratios.

In the preliminary experiment on correction of potassium deficiency (3), the best treatment proved to be 3 pounds per tree of potassium nitrate of 21–0–44 composition. When this new experiment was set up the 21–0–44 potassium nitrate was not procurable and treatment L represents a similar material made by mixing Chilean nitrate of potash 14–0–14 with sufficient supplemental muriate of potash to make the N/K_2O ratio the same as in the product used previously with success.

In setting up the experiment care was taken to use only trees as nearly comparable as possible in size and in severity of the disorder, based on a score made in October 1942. The first 12 treatments were assigned at random to the plots of trees selected in this manner. In April 1943 it was realized that by adding two treatments, in proper relation to treatments A and D, a second factorial combination of two levels each of nitrogen and potassium could be arranged. Accordingly treatment M was added, supplying the highest level of nitrogen with potassium at the same level as in treatment A, and treatment N, supplying the highest level of potassium with nitrogen at the level of treatment A. These were assigned to plots added to each replication and not strictly disposed at random in relation to the other 12 treatments.

Soil samples were taken from all plots of treatments A, B, C, D, F, H, J, M, and N in mid-August 1942 before the treatments were begun, and again in mid-August 1946 after 4 years of fertilizer treatments. These samples were taken at 0 to 6 inches, 6 to 12 inches, and 12 to 18 inches.

Composite samples of midshoot leaves without petioles were collected from representative positions on the trees of each plot of three replications in late summer of 1943, 1944, 1945, and 1946. Unfortunately because of various mishaps, such as hail damage one year, frost damage another year, and the accidental application of dolomite and superphosphate by the grower to one replication one year, it was not possible to compare the same three replications in each of the four years. Comparable samples were obtained from three replications for three years, namely 1944, 1945, and 1946, except that replication 4 was substituted for replication 1 in 1946. The samples were analyzed for nitrogen and potassium. Girth of the trunk of each tree was measured at a marked point in 1943, 1945, and 1947. Because of the frost and hail, yield records were obtained only in 1946 and 1947. Although differential applications of fertilizer were not made in 1947, yields were recorded and used because they reflect treatments given in 1946.

Presentation of Data

Nearpass, Drosdoff, and Brown (2) analyzed the soil samples and reported that exchangeable potassium was increased proportionately to the potassium applied. Exchangeable potassium was not increased under the mulches.

In the present study the source of potassium had no influence on the potassium content of the leaves, the average percentages for muriate and sulphate being 0.78 and 0.79, respectively; the corresponding percentages for nitrogen were identical. Therefore, to simplify presentation of data, similar levels of muriate and sulphate have been combined (Table III).

The nitrogen content of the leaves increased, on the average for the three years, from 1.97 per cent in the leaves from trees receiving 0.20 pound of N per tree annually to 2.23 per cent in the leaves from trees receiving 0.72 pound of N per tree annually, both in combination with the lowest level of potassium (treatments A and M, Table II). Similar differences were observed at the higher level of potassium (treatments N and D, Table II). The higher N/K_2O ratios also consistently increased the percentages of nitrogen in the leaves by amounts that have high statistical significance (Table III). The average nitrogen content of leaves from trees fertilized with nitrogen derived from Chilean potassium nitrate, treatment L, was 2.37 per cent as compared with 2.27 per cent in leaves of trees that received the same quantity of nitrogen from sodium nitrate (Table II). This difference failed to attain statistical significance at the .05 level. The highest nitrogen content, 2.42 per cent, occurred in leaves of trees mulched with vetch. In leaves of trees mulched with crotalaria the percentage of nitrogen was 2.18, significantly lower than the vetch treatment (Table II).

TABLE II—EFFECT OF MISCELLANEOUS TREATMENTS ON COMPOSITIONS OF TUNG LEAVES

Treatment	K_2O Per Tree (Pounds)	N Per Tree (Pounds)	Leaf Composition: Nitrogen (Dry Basis—Per Cent)				Leaf Composition: Potassium (Dry Basis—Per Cent)			
			1944	1945	1946	Average	1944	1945	1946	Average
A	0.35	0.20	1.99	2.01	1.91	1.97	0.49	0.69	0.69	0.62
M	0.35	0.72	2.06	2.33	2.29	2.23	0.39	0.56	0.56	0.50
N	1.52	0.20	2.00	2.10	1.88	1.99	0.71	0.95	0.98	0.88
D	1.52	0.72	2.29	2.32	2.20	2.27	0.66	0.84	0.84	0.78
L	1.52*	0.72	2.25	2.48	2.39	2.37	0.65	0.91	0.91	0.82
B	Vetch mulch	—	2.39	2.53	2.35	2.42	0.75	0.81	0.74	0.77
C	Crotalaria mulch	—	2.21	2.36	1.96	2.18	0.95	0.94	0.94	0.94
LDS at 0.05...........						0.13				0.09
LDS at 0.01..						0.17				0.12

*N from Chilean potassium nitrate instead of nitrate of soda.

The average potassium content of the leaves of trees receiving 0.35 pound of K_2O was reduced from 0.62 to 0.50 by increasing the level of nitrogen supplied from 0.20 to 0.72 pound per tree (Table II). The severity of the potassium deficiency symptoms on the foliage of the trees was correspondingly greater in the case of treatment M than in treatment A. This difference was observed consistently throughout the duration of the experiment.

At comparable levels of nitrogen (Table II) or N/K_2O ratios (Table III) the potassium content of the leaves was proportionate to the levels of potassium applied.

By October 1943 differences in severity of potassium deficiency symptoms were evident and therefore the trees were scored by the

TABLE III—EFFECT OF LEVEL OF POTASSIUM AND NITROGEN-POTASSIUM RATIO ON COMPOSITION OF TUNG LEAVES

Treatment	K_2O Per Tree (Pounds)	N Per Pound of K_2O	Leaf Composition							
			Nitrogen (Dry Basis—Per Cent)				Potassium (Dry Basis—Per Cent)			
			1944	1945	1946	Average	1944	1945	1946	Average
G, K	0.76	0.32	1.98	2.07	1.98	2.01	0.61	0.88	0.83	0.77
J, F	0.76	0.47	2.15	2.18	2 09	2.14	0.55	0.82	0.84	0.74
I, E	1.52	0.32	2.08	2.24	2.15	2.16	0.68	0.94	0.92	0 85
D, H	1.52	0.47	2.27	2.40	2.25	2.31	0.65	0.87	0.86	0.79
LDS at 0.05........						0.08				0.06
LDS at 0.01........						0.11				0.08

senior author on a scale ranging from 1 to 5, 1 representing normal leaves and 5 a condition in which practically every leaf on the tree showed the disorder. On analysis, these scores were found to be inversely proportional to the potassium and directly proportional to the nitrogen applied; the value of F for treatments was 10.56 where 4.24 is required at the .001 level. At the time that the trees were scored, leaf samples were taken for analysis. The potassium content of the leaves was found to be negatively correlated with the scores for symptoms, the value of r being —.661 where —.490 would be statistically significant at the .001 level. This indicated clearly that the symptoms scored were those of potassium deficiency.

The average gain in cross-sectional area of the trunk from 1943 to 1947 of trees fertilized with sulphate of potash was 143.4 square centimeters, while that of trees fertilized with corrsponding amounts of muriate was 128.7 square centimeters. Average yields per tree for the two seasons, 1946 and 1947, showed no corresponding difference; but in 1947 trees fertilized with sulphate of potash outyielded those fertilized with muriate of potash by 3.7 pounds per tree. The difference in gain in cross-sectional area of the trunk for 1943 to 1947 and in yield for 1947 attained statistical significance at the .05 level. It will be recalled that the two groups of trees had almost exactly equivalent amounts of nitrogen and potassium in the leaves. The differences noted above would, therefore, be attributable to the effects of the chlorine and sulphate ions. In view of the fact that the statistical odds are not high, further evidence would be desirable before drawing a definite conclusion. Although some differences in growth appear to be associated with the source of potassium, in studying effects of levels of nitrogen and potassium it is advantageous to combine the plots receiving the same levels of potassium from the two sources (Table IV). This is permissible because statistical analysis showed no interactions of source with level of potassium or with N/K_2O ratio.

At the low level of potassium, gain in cross-sectional area of the trunks was increased from 104.4 at the lower N/K_2O ratio to 122.9 square centimeters at the higher N/K_2O ratio. There was a similar but smaller gain at the higher level of potassium; the corresponding readings were 152.3 and 164.6 square centimeters (Table IV). At the high level of potassium, gains in cross-sectional area of trunks exceeded those at the low level of potassium by wide differences (Table

TABLE IV—EFFECT OF LEVEL OF POTASSIUM, AND NITROGEN-POTASSIUM RATIO ON AVERAGE YIELDS OF TUNG TREES (1945–1946) AND ON GAIN IN CROSS-SECTIONAL AREA OF TRUNK (1943–1947)

Treatment	K_2O Per Tree (Pounds)	N Per Pound of K_2O	Air-Dry Fruit Per Tree (Pounds)	Gain, Cross-Sectional Area of Trunk (Square Centimeters)
G, K	0.76	0.32	14.4	104.4
J, F	0.76	0.47	19.1	122.9
I, E	1.52	0.32	24.7	152.3
D, H	1.52	0.47	28.1	164.6
LDS at 0.05			3.8	18.6
LDS at 0.01			5.0	24.7
LDS at 0.001			6.5	32.2

IV); but since the amount of nitrogen used was proportionate to the level of potassium these gains may be due in part to the nitrogen. Comparison of treatments A, M, N, and D (Table V), which differ by actual levels of each nutrient, indicates that both nitrogen and potassium independently effectuated substantial gains in growth in this orchard. The two mulch treatments showed large gains over the check, treatment A.

TABLE V—EFFECT OF MISCELLANEOUS TREATMENTS ON AVERAGE YIELDS OF TUNG TREES (1945–1946) AND ON GAIN IN CROSS-SECTIONAL AREA OF TRUNK (1943–47)

Treatment	K_2O Per Tree (Pounds)	N Per Tree (Pounds)	Air-Dry Fruit Per Tree (Pounds)	Gain, Cross-Sectional Area of Trunk (Square Centimeters)
A	0.35	0.20	11.2	75.5
M	0.35	0.72	26.9	111.5
N	1.52	0.20	18.6	112.9
D	1.52	0.72	29.3	157.2
L	1.52	0.72	28.1	154.8
B	Vetch mulch		25.8	138.3
C	Crotalaria mulch		22.1	146.2
LDS at 0.05			5.3	26.3
LDS at 0.01			7.1	35.0
LDS at 0.001			9.2	45.5

In general, yields were closely associated with gains in trunk growth. The yield in 1947 was increased by the use of sulfate of potash to a point almost reaching statistical significance at the .05 level. The gains effectuated by the higher N/K_2O ratio were 4.7 and 3.4 pounds air-dry fruit per tree, respectively, at the low and high levels of potassium. The higher levels of potassium with proportional levels of nitrogen brought about still larger gains, averaging 9.6 pounds air-dry fruit per tree (Table IV). The data in Table V also show that both nitrogen and potassium effectuated large gains in yield. The mulched plots outyielded the control, treatment A by 10.9 to 14.6 pounds air-dry fruit per tree.

SUMMARY

In this orchard on Red Bay fine sandy loam both potassium and nitrogen were deficient.

Applications of 1.52 pounds of K_2O per tree for the 4-year period of this experiment eliminated the potassium deficiency symptoms; but

when a low level of potassium was supplied a liberal application of nitrogen tended to aggravate the disorder.

The crotalaria mulch most effectively corrected the potassium deficiency symptoms.

The potassium content of the leaves was lowered by increasing the amount of nitrogen supplied.

The vetch mulch increased the nitrogen content of the leaves to a greater degree than any of the mineral applications of nitrogen.

The nitrogen content of the leaves however was increased proportionately to the amount of nitrogen supplied.

The composition of leaves from trees fertilized with muriate of potash was practically identical with the composition of leaves from trees fertilized with sulfate of potash.

Gains in cross-sectional area of the trunks and yield of air-dry fruit per tree were increased independently by both nitrogen and potassium.

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Response of Bearing Tung Trees to Nitrogen, Phosphorus, and Potassium Fertilizers

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THE prevailing orchard management practice in the western part of the tung belt in 1942 consisted of growing and turning under a legume green manure crop which was fertilized at planting with an application of about 500 pounds of basic slag and 40 pounds of 50 per cent muriate of potash per acre. Good production of tung fruit had been obtained without further fertilization, but there were indications that better production might be possible. An experiment was initiated in the fall of 1942 in a 5-year-old tung orchard that received the basic cover crop fertilization to learn whether additional fertilizaion with nitrogen, phosphorus, and potassium would result in increased yields. The orchard had been planted in 1948 near Bush, Louisiana, on a site classified as predominantly Ora sandy loam soil.

Three levels of each element were used annually, beginning in the spring of 1943. The low level of each element was that supplied by the soil and cover crop, or applied directly to the cover crop. The supplementary fertilizers were applied in a band around the trees at rates varying with the age of the trees. At the intermediate level each tree received 0.08 pound of N, 0.08 pound of P_2O_5, and 0.06 pound of K_2O per year of attained age. For example, in 1943, the trees being 5 years old, the intermediate rate per tree for N was 0.40 pound; for P_2O_5, 0.40 pound; and for K_2O, 0.30 pound. At the third or high level the amounts of each element applied were twice those used at the intermediate level. In 1943 and 1944 one-third of the nitrogen was supplied as nitrate of soda and two-thirds as sulfate of ammonia, but in subsequent years all of the nitrogen was supplied as ammonium nitrate. Phosphorus was supplied as 20 per cent superphosphate, and potash as 50 per cent muriate of potash.

The experiment was set up in a balanced partially confounded factorial design with four replications of 27 treatments, representing all possible combinations of the three levels of the three elements (Yates, 10). Each replication was subdivided into three blocks of nine treatments each. Each treatment plot consisted of six trees, selected for uniformity of size and for uniformity of bearing as indicated by old fruit stems. Girth of the trunk of each tree was measured at a marked point after the 1942 growth had been completed, and annually thereafter. The girth measurements were converted to cross-sectional area of the trunk, and an analysis of variance of these 1942 data revealed differences between blocks which were significant at the .001 level. There were no statistically significant differences between plots assigned to the various treatments except that in plots for testing levels of potassium, trees assigned to the intermediate level were smaller than those assigned to the low and high levels by a difference that would occur by chance only once in 20 trials. The 1942 cross-sectional area data were used to adjust the later data by the method of covariance, but no increase in precision was gained thereby. The yield of

air-dry fruit from the individual trees in the experiment was recorded in 1942 and also mean number of shoots, the mean total length of shoots, and the mean number of fruits per previous year's terminal. An analysis of variance showed no statistically significant differences between plots assigned to the different treatments for any of these determinations.

Fruits were harvested in the usual commercial manner, weighed, and a sample taken by which the field weights were adjusted to a uniform air-dry basis. One hundred fruits were used for the determination of the mean weight per fruit, and the percentage of kernel, after having been brought to moisture equilibrium over a standard solution of calcium chloride at 75 degrees F. The kernels from these 100 fruits were thoroughly mixed and oil was determined by suitable methods in a random sample of approximately 100 kernels.[1]

Samples of about 48 leaves each were collected annually in August for determination of nitrogen, phosphorus, potassium, calcium, and magnesium. The midshoot leaf was removed without its petiole from each of eight modal length shoots from representative positions on four sides of each tree in each plot receiving the low and each plot receiving the high level of each element. Nitrogen, phosphorus, potassium, calcium, and magnesium were determined by methods described by Drosdoff (3).[2]

RESULTS

Response to Nitrogen:—No significant differences in the yields of fruit in 1943 were observed (Table I). This was to be expected be-

TABLE I—EFFECT OF FERTILIZERS ON YIELD OF AIR-DRY TUNG FRUIT PER TREE (POUNDS)

Fertilizer Element	Level	1942*	1943	1944	1945	1946	Total (1944, 1945, 1946)
Nitrogen	Low	8.0	22.9	24.8	37.8	36 0	98.6
	Intermediate	8.6	23.9	31 2	39.5	52.1	122 8
	High	8 6	22.8	35.2	38.9	61.8	135.9
F observed		†	†	22.58	†	86.29	77.07
Phosphorus	Low	7.8	23.3	29.8	37.8	47.1	114.7
	Intermediate	9.2	23.8	30.2	39.6	50.3	120.1
	High	8.2	22.5	31.3	38.8	52.5	122.6
F observed		†	†	†	†	3.83	3.61
Potassium	Low	7.9	23.6	28.9	38.9	45.6	113.4
	Intermediate	P 8.8	23.3	30.8	38.6	51.4	120.8
	High	8.5	23.3	31.6	38.7	52.9	123.2
F observed		1.10	†	1.59	†	7.40	5.53

*Fertilizer applications were started in 1943. Yield data for 1942 and 1943 were not effected by treatments but are presented to show the uniformity of the selected trees.
†Mean square for treatments less than mean square for error.
F required for statistical significance at 0.05, 3.13; at 0.01, 4.92; at 0.001, 7.76.

[1]The writer is indebted to A. J. Loustalot, assistant plant physiologist (resigned), and S. G. Gilbert, associate plant physiologist, U. S. Field Laboratory for Tung Investigations, Gainesville, Florida, for the oil analyses.

[2]The writer is indebted to Dr. Matthew Drosdoff, soil technologist, U. S. Field Laboratory for Tung Investigations, Gainesville, Florida, for the leaf analyses.

cause the fruit buds for that crop had been formed prior to the application of the fertilizer. The intermediate level of nitrogen resulted in 25.8 per cent and the high level resulted in 41.9 per cent increase in yield in 1944 over that at the low level. The differences are of very high statistical significance and great practical importance.

The yield of air-dry fruit in 1945 from the trees that had the higher levels of nitrogen application was larger than that from the trees having low levels of application, but the difference was too small for significance. Biennial bearing in tung has been reported by Potter, Sitton, and McCann (6). The biennial tendency probably was responsible for the lack of significant differences in yield in 1945. Trees receiving the low levels of nitrogen in 1943 set and matured a comparatively small crop of fruit in 1944 and a larger crop in 1945. On the other hand the trees at a high level of nitrogen set and matured such a large crop in 1944, that as a result only a partial crop was set in 1945.

In 1946 the trees at the high level of nitrogen produced a crop that was 25.8 pounds, or 71.7 per cent more than that of trees at the low level. Trees at the intermediate level yielded 44.7 per cent more than trees in the low level plots, differences of very high statistical significance. The combined yield for 1944, 1945, and 1946 was 24.2 and 37.3 pounds more from the intermediate and high levels, respectively, than from the low level, differences that attain very high statistical significance. In this orchard there are about 70 trees per acre; therefore, on an acre basis, the difference in yield of air-dry fruit between the low level and the high level of nitrogen was 2,611 pounds as the result of the application of 56 pounds of nitrogen in 1943, 67 pounds in 1944, and 78 pounds in 1945.

Effect of Nitrogen Upon Fruiting:—The higher levels of nitrogen resulted in an increase in 1943 and 1944 in the mean number of shoots from the terminal buds of the previous season (Table II). In 1943 the mean number of shoots at the intermediate level of nitrogen was 6.8 per cent and at the high level, 10.2 per cent greater than on the low level, differences which are of very high statistical and practical significance. The tung tree produces fruit from the terminal buds of the preceding year's shoots; hence the potential productive capacity of the tree depends on the number of shoots.

In addition to the increase in number of terminals from which fruit could be produced, the higher levels of nitrogen increased the mean number of pistillate flowers differentiated in each terminal bud during 1943. Unless destroyed by frost, practically all pistillate flowers of tung set fruit; hence, the number of pistillate flowers differentiated in any season can be accurately determined by counting the fruit set the following spring. In this manner it was found that in 1943 the numbers of pistillate flowers differentiated per terminal bud at the intermediate and high levels of nitrogen were, respectively, 25.6 and 33.5 per cent greater than differentiated at the low level and are of very high statistical significance. The increase in the mean number of 1943 shoots and in the mean number of 1944 fruit set per shoot resulted in the increase in yield of fruit per tree in 1944 as recorded above.

TABLE II—EFFECT OF FERTILIZERS ON NUMBER AND LENGTH OF SHOOTS AND NUMBER OF FRUITS PER TERMINAL OF THE PREVIOUS SEASON

Fertilizer Element	Level	Mean Number of Shoots Per Previous Year's Terminal			Mean Total Length of Shoots Per Previous Year's Terminal (Cms)			Mean Number Fruit Per Previous Year's Terminal (1944)
		1942*	1943	1944	1942*	1943	1944	
Nitrogen	Low	3.35	2.05	2.43	116.8	51.8	43.1	1.64
	Intermediate	3.44	2.19	2.60	123.1	62.6	50.1	2.06
	High	3.35	2.26	2.64	121.9	69.7	52.6	2.19
F observed		†	8.00	11.11	1.32	20.15	13.43	22.62
Phosphorus	Low	3.34	2.14	2.55	119.1	61.4	47.2	1.94
	Intermediate	3.46	2.15	2.52	120.8	60.3	47.6	1.86
	High	3.34	2.21	2.61	121.9	62.3	50.9	2.10
F observed		1.65	1.20	1.69	†	†	2.31	4.15
Potassium	Low	3.40	2.18	2.52	120.4	61.2	47.4	1.79
	Intermediate	3.34	2.10	2.55	117.3	60.0	47.8	2.07
	High	3.40	2.23	2.61	124.1	63.0	50.6	2.03
F observed		†	3.20	1.81	1.37	†	1.62	6.46

*Fertilizer applications were started in 1943. The 1942 data are presented to show the uniformity of the trees selected.
†Mean square for treatments less than mean square for error.
F required for statistical significance at 0.05, 3.13; at 0.01, 4.92; at 0.001, 7.76.

The Effect of Nitrogen Upon Growth of the Tung Tree:—In addition to the increase in number and length of shoots, the higher levels of nitrogen accelerated growth, as determined by increased in cross-sectional area of the trunk of the tung tree, in 1943, 1944, 1945, and 1946 (Table III). Each season differences of very high statistical significance occurred. At the end of the 1946 growing season the trees in plots at the intermediate level of nitrogen were 13.6 per cent larger and those in plots at the high level were 24.5 per cent larger than those

TABLE III—EFFECT OF FERTILIZERS ON CROSS-SECTIONAL AREA OF TRUNKS OF TUNG TREES

Fertilizer Element	Level	Cross-Sectional Area of Tree Trunks (Sq Cms) 1942*	Increase in Cross-Sectional Area (Sq Cms) in the Season of				Cross-Sectional Area of Tree Trunks (Sq Cms) December 1946
			1943	1944	1945	1946	
Nitrogen	Low	106.0	45.8	35.4	34.9	40.7	262.4
	Intermediate	105.9	54.0	40.2	47.9	50.9	298.1
	High	109.2	59.8	43.8	53.8	61.3	326.7
F observed		†	38.21	24.25	58.87	82.46	44.73
Phosphorus	Low	107.7	53.8	40.0	44.1	49.8	294.3
	Intermediate	108.7	53.8	40.6	46.0	52.4	300.3
	High	104.7	52.0	38.8	46.6	50.8	292.6
F observed		†	†	1.10	1.08	1.32	†
Potassium	Low	109.5	51.6	39.6	41.4	46.5	287.4
	Intermediate	102.6	51.7	38.1	45.2	49.1	285.4
	High	109.0	56.4	41.8	50.0	57.4	314.4
F observed		3.40	5.85	4.62	11.92	25.58	11.27

*Fertilizer applications were started in 1943. The 1942 data are presented to show the relative size of the trees when the experiment was started.
†Mean square for treatments less than mean square for error.
F required for statistical significance at 0.05, 3.13; at 0.01, 4.92; at 0.001, 7.76.

at the low level. The differences are of very high statistical significance. Much of the increase in yield of air-dry fruit is associated with the increase in size and corresponding increase in potential productive capacity of the trees.

Effect of Nitrogen on Fruit Composition:—The percentage of oil in the kernels of fruit from the 1943 crop was decreased by the higher levels of nitrogen (Table IV), but the percentage of kernel was increased (Table V), which resulted in a net increase in percentage of oil in the whole fruit (Table VI). The differences in the percentage of oil in the kernel are greater than those required for statistical significance at the .01 level; the gains in the percentage of kernel and the percentage of oil in the whole fruit are greater than necessary at the

TABLE IV—EFFECT OF FERTILIZERS ON OIL CONTENT OF TUNG KERNELS AT APPROXIMATELY 4.0 PER CENT MOISTURE CONTENT

Fertilizer Element	Level	1943 (Per Cent)	1944 (Per Cent)	1945 (Per Cent)	1946 (Per Cent)
Nitrogen	Low	66.3	62.0	64.4	66.0
	Intermediate	65.8	60.9	—	63.5
	High	65.2	60.0	61.4	61.5
F observed		5.23	51.03	32.59	80.07
Phosphorus	Low	65.6	61.2	62.9	63.7
	Intermediate	65.9	60.8	—	63.6
	High	65.8	60.8	62.9	63.6
F observed		*	2.36	*	*
Potassium	Low	65.3	60.7	62.3	62.2
	Intermediate	66.2	61.1	—	63.9
	High	65.8	61.0	63.5	64.7
F observed		3.24	1.69	5.28	25.13

*Mean square for treatments less than mean square for error.
F required for statistical significance at 0.05, 3.13; at 0.01, 4.92; at 0.001, 7.76; except that for 1945 4.32 is required at 0.05, 8.02 at 0.01, and 14.59 at 0.001.

TABLE V—EFFECT OF FERTILIZERS ON KERNEL CONTENT OF WHOLE TUNG FRUIT AT 10.0 PER CENT MOISTURE CONTENT

Fertilizer Element	Level	1942* (Per Cent)	1943 (Per Cent)	1944 (Per Cent)	1945 (Per Cent)	1946 (Per Cent)
Nitrogen	Low	33.4	33.6	33.3	31.3	31.1
	Intermediate	33.7	35.6	35.0	—	32.6
	High	34.2	35.8	36.1	34.5	33.4
F observed		1.30	20.83	32.24	18.31	12.65
Phosphorus	Low	33.4	34.9	34.7	32.6	32.2
	Intermediate	34.1	34.9	34.6	—	32.2
	High	34.0	35.2	35.2	33.2	32.8
F observed		1.08	†	1.43	†	1.27
Potassium	Low	34.0	34.9	34.3	32.0	30.9
	Intermediate	33.5	34.8	34.6	—	32.5
	High	33.9	35.3	35.5	33.8	33.7
F observed		†	†	5.89	5.34	19.65

*Fertilizer applications were started in 1943. The 1942 data are presented to show the uniformity of the fruit before the experiment was started.
†Mean square for treatments less than mean square for error.
F required for statistical significance at 0.05, 3.13; at 0.01, 4.92; at 0.001, 7.76; except that for 1945 4.32 is required at 0.05, 8.02 at 0.01, and 14.59 at 0.001.

TABLE VI—EFFECT OF FERTILIZERS ON OIL IN WHOLE TUNG FRUIT AT 10.0 PER CENT MOISTURE CONTENT

Fertilizer Element	Level	1943 (Per Cent)	1944 (Per Cent)	1945 (Per Cent)	1946 (Per Cent)
Nitrogen	Low	21.4	20.7	20.1	20.6
	Intermediate	22.5	21.3	—	20.7
	High	22.4	21.7	21.2	20.5
F observed		10.69	8.47	3.29	*
Phosphorus	Low	22.0	21.3	20.5	20.5
	Intermediate	22.1	21.0	—	20.5
	High	22.2	21.4	20.8	20.8
F observed		*	1.08	*	*
Potassium	Low	21.9	20.8	20.0	19.2
	Intermediate	22.2	21.1	—	20.8
	High	22.3	21.7	21.4	21.8
F observed		1.17	5.96	6.15	25.28

*Mean square for treatments less than mean square for error.
F required for statistical significance at 0.05, 3.13; at 0.01, 4.92; at 0.001, 7.76; except that for 1945 4.32 is required at 0.05, 8.02 at 0.01, and 14.59 at 0.001.

.001 level. The percentage of oil in the kernel, percentage of kernel in the whole fruit, and percentage of oil in the whole fruit in the 1944 crop exhibited the same trends as those in he 1943 crop, but the differences were greater.

Similar trends with wider differences in percentage of oil in the kernel, the percentage of kernel in the whole fruit, and the percentage of oil in the whole fruit were again observed in the 1945 crop. However, the fruit from only 32 plots, representing the high and low level of each element, and the combination thereof, were analyzed in 1945. Hence considerable precision was lost, and in consequence the differences in the percentage of oil in the whole fruit did not attain statistical significance at the conventional .05 level.

The percentage of kernel in the whole fruit of the 1946 crop increased with the higher levels of nitrogen by approximately the same amount as in the previous crops, but the percentage of oil in the kernel decreased with the higher levels more than with any previous crop. Consequently there was no significant gain in the percentage of oil in the whole fruit such as occurred in 1943, 1944 and presumably in 1945.

The net result of the greater yields of air-dry fruit and the greater percentage of oil in the whole fruit was an increase in production of tung oil of 1.40 and 2.40 pounds per tree for the intermediate and the high levels of nitrogen, respectively, in 1944 (Table VII). The production of oil in the 1945 crop was 0.7 pound per tree greater from the high than from the low level of nitrogen. Although there was no significant difference in percentage of oil in the whole fruit of the 1946 crop resulting from the different levels of nitrogen, the differences in yields of air-dry fruit was responsible for yields of oil of 3.4 and 5.4 pounds more per tree, respectively, by the intermediate and high levels of nitrogen than by the low level of nitrogen.

Response to Phosphorus:—Prior to 1946 there was no significant response to the different levels of phosphorus in yield of tung fruit, in

TABLE VII—EFFECT OF FERTILIZERS ON YIELD OF TUNG OIL PER TREE (POUNDS)

Fertilizer Eelemnt	Level	1943	1944	1945	1946
Nitrogen	Low	4.92	5.24	7.50	7.47
	Intermediate	5.42	6.64	—	10.89
	High	5.06	7.64	8.20	12.82
F observed		1.12	25.27	1.02	65.16
Phosphorus	Low	5.15	6.34	7.38	9.76
	Intermediate	5.29	6.34	—	10.35
	High	5.01	6.83	8.32	11.06
F observed		1.08	1.40	1.86	3.77
otassium	Low	5.18	6 03	7.77	8.88
	Intermediate	5.18	6.64	—	10 75
	High	5.09	6.84	8.28	11.54
F observed		*	3.06	*	16.53

*Mean square for treatments less than mean square for error.
F required for statistical significance at 0.05, 3.13; at 0.01, 4.92; at 0.001, 7.76; except that for 1945 4.32 is required at 0.05, 8.02 at 0.01, and 14.59 at 0.001.

number or length of shoots per previous season's terminal bud, in increase in cross-sectional area of the tree trunks, in percentage of oil in the kernel, in percentage of kernel in the whole fruit, or in percentage of oil in the whole fruit. Differences between the number of fruit per terminal in 1944 at the three levels of phosphorus (Table II) attain statistical significance at the .05 level, but they seem anomalous and probably are simply due to chance. In 1946 the yields of air-dry fruit were 3.2 and 5.4 pounds more from plots at the intermediate and high levels of phosphorus, respectively, than from those at the low level of phosphorus. The differences are statistically significant. Although there were no differences in percentages of oil in the whole fruit, there were increases in yield of tung oil of 0.6 and 1.3 pounds per tree, respectively, at the intermediate and high levels of phosphorus over that produced at the low level as a result of the differences in yield of fruit. These differences are also significant.

Response to Potassium:—Trees at the intermediate level of potassium produced 1.9 pounds more, and those at the high level 2.7 pounds more air-dry fruit per tree in 1944 than did trees at the low level; but these differences do not attain statistical significance. There were no significant differences in 1945 in yield of air-dry fruit, or yield of oil per tree associated with the different levels of potassium.

In 1946 the trees at the intermediate and high levels of potassium produced 5.8 and 7.3 pounds more air-dry fruit per tree, respectively, than those at the low level, differences of high statistical significance. Since potassium had no appreciable effect on yield prior to 1946, the gains in total yield for the 3-year period, 1944 to 1946 inclusive, are essentially the same as for the 1946 season.

The mean number of shoots in 1943 per 1942 terminal bud was 0.05 greater at the high level of potassium than at the low level, and 0.13 greater than at the intermediate level, differences which barely attain statistical significance. The mean number of pistillate flowers in 1944 per 1943 terminal bud was 0.28 and 0.24 greater, respectively, at the intermediate and high levels of potassium than at the low level,

differences that are significant at the .01 level. However, as previously noted, the combined effect of the increase in number of 1943 shoots and of pistillate flowers set was not sufficient to result in significant increase in yield of air-dry fruit.

The higher levels of potassium resulted in significantly increased growth of the tung trees each season as determined from cross-sectional area increased. The trees assigned to the intermediate level of potassium plots were significantly smaller at the initiation of the experiment than the trees assigned to the low and high levels of potassium plots, and had not attained equal size even by December 1946, though they had increased in cross-sectional area by 4.9 square centimeters more than had the trees at the low level of potassium. Trees at the high level of potassium had increased in cross-sectional area 27.5 square centimeters more than had those at the low level.

Influence of Potassium Upon Fruit Composition:—The intermediate level of potassium increased percentage of oil in the kernel of the 1943 crop by 0.9 and the high level by 0.5 as compared with the percentage for the low level of potassium, differences significant at the .05 level. The percentage of oil in the whole fruit, however, was increased only 0.3 and 0.4, respectively, by the intermediate and high levels of potassium, as compared with the percentage of oil in the whole fruit at the low level of potassium, differences too small for statistical significance at the .05 level.

There were no significant differences in percentage of oil in the kernels of the fruit of the 1944 crop, but the kernel content was 0.3 and 1.2 percentage units greater in fruits from the intermediate and high levels of potassium, respectively, than in fruit from the low level, differences that are highly significant. Likewise the intermediate and high levels resulted in 0.3 and 0.9 percentage units more oil in the whole fruit, respectively, than in the fruit of the low level of potassium, differences that are also highly significant.

The yield of oil per tree was 0.61 and 0.81 pounds more for the intermediate and high levels, respectively, than for the low level of potassium, differences slightly smaller than required for significance at the 0.5 level.

The trends in oil content of the kernel, kernel content of the fruit, and oil content of the fruit, associated with the three levels of potassium in 1943 and 1944, were again observed in 1945.

In fruit of the 1946 crop there were, respectively, 1.7 and 2.5 percentage units more oil in the kernels with the intermediate and high levels of potassium than with the low level, and the difference is of very high statistical significance. The percentage of kernel in the fruit was likewise increased by the higher levels of potassium, being, respectively, 1.6 and 2.8 percentage units greater at the intermediate and high levels than at the low level. The combined effect of potassium on the percentage of oil in the kernel and the percentage of kernel resulted in an increase in percentage of oil in the whole fruit of 1.6 and 2.6 percentage units respectively for the intermediate and high levels over that for the low level of potassium. These differences are of very high statistical significance.

The net result of the increase in yield of air-dry fruit per tree and in increase in per cent of oil in the fruit was a very highly significant increase in the oil yield per tree. The increase was 1.87 and 2.66 pounds per tree, respectively, for the intermediate and high levels over the yield for the low level of potassium.

The data thus far presented have to do with over-all average effects of each element. While these accurately present the most important results, it is necessary to consider certain interactions in order to complete the picture. There was a greater tendency for nitrogen to increase total yield of air-dry fruit per tree for the 3 years, 1944 to 1946 inclusive, at the high levels of phosphorus than at the low levels (Table VIII). Each entry in Table VIII is the mean of 12 plots, and

TABLE VIII—Interaction of Levels of Nitrogen With Levels of Phosphorus on the Total Yield of Air-Dry Fruit Per Tree (1944–1946 Inclusive)

Level of Nitrogen	Level of Phosphorus (Pounds)		
	Low	Intermediate	High
Low	100.6	94.4	100.9
Intermediate	119.6	127.0	121.7
High	123.6	138.9	145.3

F observed 3.63. F required for statistical significance at 0.01, 3.60.

some precision is lost, as compared to entries in Table I, each of which is the mean of 36 plots; hence certain readings appear inconsistent, for example, the lower yield at intermediate nitrogen and high phosphorus than at intermediate nitrogen and phosphorus. Nevertheless, in general, better yields were obtained when high levels of nitrogen and phosphorus were combined than when high levels of either one were used with low levels of the other. The interaction attains statistical significance at the .01 level.

A similar, but less pronounced interaction, occurred between nitrogen and potassium; and a second order interaction between all three elements, supported by an F value of 13.16 where 3.87 is required at .001, indicated that somewhat the best yields were obtained with high levels of all three elements; for example the yield for the three years 1944 to 1946 at the high levels of all three elements was 142.4 pounds per tree which is greater by from 4.9 to 15.8 pounds per tree than the yield from any combination of two elements at the high level with the other element at the low level. A fact of much significance is that these interactions did not appear until the experiment had been in progress 4 years. At the outset nitrogen improved yields irrespective of the levels of phosphorus and potassium, but ultimately the gains due to nitrogen tended to be limited by the levels of the other two elements.

In 1944 several interactions affecting fruit composition were observed. Oil in the kernel tended to be decreased by nitrogen to a greater extent at the intermediate and high levels of phosphorus than at the low level. This interaction attains statistical significance at the .001 level. An interaction, significant at the .01 level, similar to, but exactly opposite in trend, to that just described, was observed in

kernel content of the fruit. The higher the level of phosphorus, the greater the increase in kernel content due to nitrogen. An interaction between phosphorus and potassium, supported by odds of 19 to 1, was also observed; these elements were more effective in increasing kernel content of the fruit when used in combination than when used separately. Nitrogen and phosphorus when combined effected larger increases in oil content of the whole fruit than when used independently, and the same was true of phosphorus and potassium. The N.P and P.K interactions are supported by F values of 4.14 and 3.25, respectively, where 2.50 is required at the .05 level of significance and 3.60 at the .01 level.

Effect of Treatment on Leaf Composition:—Data showing all statistically significant main effects of treatment on leaf composition are presented in Table IX. Beginning in August 1943, the nitrogen content of the leaves from trees at the high level of nitrogen was higher than that of leaves from trees at the low level. In 1943 the difference was 0.15 percentage units and was greater than needed at the .01 level of significance. The differences were 0.19, 0.26, and 0.31 percentage units in 1944, 1945, and 1946 respectively, greater than needed for the .001 level of significance. The nitrogen content of the

TABLE IX—MINERAL CONTENT OF TUNG LEAVES IN AUGUST ASSOCIATED WITH THE ANNUAL APPLICATIONS OF FERTILIZERS (1943–1946 INCLUSIVE)*

Fertilizer Element	Level	Element Significantly Affected	Content of Element in Leaves, Dry Basis (Per Cent)			
			1943	1944	1945	1946
Nitrogen	Low	Nitrogen	2.31	2.13	2.24	1.85
	High	Nitrogen	2.46	2.32	2.50	2.16
Least significant difference at 0.001			0.09**	0.13	0.09	0.16
	Low	Potassium	0.91	0.87	0.84	0.75
	High	Potassium	0.90	0.82	0.76	0.66
Least significant difference at 0.01			†	†	†	0.08
	Low	Calcium	—	—	2.12	1.89
	High	Calcium	—	—	1.98	2.05
Least significant difference at 0.01			—	—	0.12**	0.16
	Low	Magnesium	—	—	0.38	0.34
	High	Magnesium	—	—	0.39	0.44
Least significant difference at 0.001			—	—	†	0.08
Phosphorus	Low	Phosphorus	0.138	0.122	0.159	0.140
	High	Phosphorus	0.145	0.128	0.179	0.168
Least significant difference at 0.001			0.006	†	0.009**	0.024
	Low	Calcium	—	—	1.96	1.85
	High	Calcium	—	—	2.14	2.09
Least significant difference at 0.001			—	—	0.16	0.22
Potassium	Low	Potassium	0.86	0.76	0.70	0.57
	High	Potassium	0.94	0.93	0.90	0.84
Least significant difference at 0.001			0.07**	0.10	0.16	0.11
	Low	Magnesium	—	—	0.45	0.48
	High	Magnesium	—	—	0.32	0.31
Least significant difference at 0.001					0.06	0.08

*Only the data with significant differences between treatments occuring one or more seasons are presented.
**Least significant difference at 0.01.
†Difference smaller than required for significance at 0.05 level.

leaves was not significantly affected by application of phosphoric or potassic fertilizers.

The percentage of potassium in the leaves from trees at the high level of nitrogen was smaller by 0.01, 0.05, 0.08, and 0.09 percentage units in 1943, 1944, 1945, and 1946, respectively, than in those at the low level of nitrogen; but only in 1946 was the difference great enough to attain statistical significance.

The percentage of magnesium in the leaves from plots with the high level of nitrogen was higher in 1945 than from the low level of nitrogen plots, but the difference, 0.01, was not significant. In 1946 the difference was 0.10 percentage units, and of very high statistical significance.

The content of phosphorus in the leaves was not significantly affected by nitrogen. Nitrogen fertilization had no consistent effect on the content of calcium.

The high level of phosphorus resulted in a higher percentage of phosphorus in the mid-shoot leaves in August than in similar leaves from trees at the low level. In 1943 and 1946 the differences were greater than needed for significance at the .001 level; in 1945 they were greater than required at .01. The effect of phosphoric fertilizer on the content of nitrogen, potassium, and magnesium was not significant. The per cent of calcium was higher in 1945 and 1946 in leaves from the high level than from the low level of phosphorus applications, with differences greater than needed for the .001 level of significance. The increase in calcium probably resulted from the calcium carried in the superphosphate applied.

The high level of potassium resulted in a greater percentage of potassium in the leaves as compared with the leaves from the low level of potassium applications; and the differences, beginning in 1944, were greater than needed for the .001 level of significance. The application of potassium did not significantly affect the content of nitrogen, phosphorus, or calcium in the leaves, but magnesium was 0.13 and 0.17 percentage units less in 1945 and 1946, respectively, in leaves at the high level of potassium than in similar leaves at the low level of potassium, and the differences are greater than needed for the .001 level of significance. This result is in agreement with reports of Hoagland (4), Lilleland and Brown (5), and Boynton and Compton (2).

The percentage of potassium in the leaves of the high level of potassium plots was 0.94 in 1943 and declined by 0.01, 0.04, and 0.10 in 1944, 1945, and 1946, respectively. Although the downward trend has been small, it may be an indication that the high level of potassium application is not sufficient to meet the requirements of trees in heavy producion. Sell and co-workers (7) reported mature dry fruit to have 1.58 per cent of potassium. Very likely the fruit from trees at the high level of potassium fertilization had an even higher percentage. Assuming that the fruit contained only 1.58 per cent of potassium, the crop removed 0.37, 0.50, 0.61, and 0.84 pound of potassium per tree, respectively, in 1943, 1944, 1945, and 1946 on the average for all plots at the high level of potassium. The total amount applied both directly to the tree and indirectly through the cover crop was 0.70,

0.81, 0.90, and 1.00 pound per tree, respectively, in the four successive years. As yields have increased the amount removed in the fruit has approached the total applied, and it is evident that the trees have had to depend to a considerable extent on available potassium of the soil to provide amounts required for vegetative growth. Again assuming 1.58 per cent potassium in the fruit, the average crop from all trees at the high level of nitrogen removed 0.36, 0.56, 0.61, and 0.98 pound of potassium per tree in 1943, 1944, 1945, and 1946, respectively. For those trees receiving the high level of nitrogen and the high level of potassium, the percentage of potassium in the leaves for the four successive years were respectively, 0.96, 0.95, 0.89, and 0.76; for those trees receiving nitrogen at the high level and potassium at the low level, the corresponding percentages of potassium in the leaves were 0.85, 0.70, 0.62, and 0.56. In this case only 0.21 pound of potassium was applied per tree per year, and much of the potassium in the crop must have been drained from the soil or from reserves in storage tissues of the tree. Where potassium was applied at the high level and nitrogen at the low level, the percentage of potassium in the leaves was maintained at the original level, the respective readings for the years 1943 to 1946 being 0.94, 0.92, 0.91, and 0.92.

There was a positive correlation of 0.546 between the percentage of nitrogen in the leaf in 1943 and the yield in 1944, and a positive correlation of 0.701 between the 1945 percentage of nitrogen and the 1946 yield, where a coefficient of 0.554 is needed for significance at the .001 level. However, between the percentage of nitrogen in the leaf in 1944, a year of heavy crop, and the yield in 1945, the correlation coefficient was —0.047, which is of no significance.

Thomas (9), Shear, Crane, and Myers (8), and others have advanced the hypothesis that the actual amount of any element present in a plant is less important than the balance between all elements present. An unsuccessful attempt was made to find a consistent relation between a number of different sums and ratios of elements in the leaves and yield of fruit the following year.

Discussion and Conclusions

The application of nitrogenous fertilizers in a band around the tung trees in the Spring at rates of 0.08 and 0.16 pound per tree per year of attained age increased the number of new shoots and the mean number of pistillate flowers initiated, which resulted in increased yield of tung fruit the following year. Fertilization at the high rate in 1943, 1944, and 1945 has increased the production to an average of 61.8 pounds of air-dry fruit per tree in 1946 as compared with 36.0 pounds per tree on plots receiving only that nitrogen supplied by the soil and green manure crops. The orchard in which the experiment is located has approximately 70 trees per acre and on that basis the high nitrogen plots produced 4,326 pounds of air-dry fruit per acre in 1946, and the low nitrogen plots produced 2,520 pounds; for the three crops (1944, 1945, and 1946) the total yields were 9,513 and 6,902 pounds per acre, respectively. The trees at the high level of nitrogen were 24.5 per cent larger at the end of the 1946 season than the trees at the low

level and therefore have a greater number of shoot terminals and a greater potential for future production.

The application of potassium at the rates of 0.06 and 0.12 pound of K_2O per tree per year of attained age in 1943, 1944, and 1945 had very little effect on yields of tung fruit in 1944 and 1945; but in 1946 the higher levels of potassium effected highly significant gains over the yields from trees which had no potassium except the residual amounts in the soil and the 50 pounds of 50 per cent muriate of potash applied broadcast to the green manure crop. Total yield for the three crops of 1944, 1945, and 1946 from plots at the low level of potassium was 113.4 pounds of air-dry fruit per tree, and from the high level of potassium plots, 123.2 pounds per tree. In addition to the direct effect of potassium, there was a trend toward higher yields where nitrogen was used in combination with the higher levels of potassium.

Phosphorus, applied at the rate of 0.08 and 0.16 pound of P_2O_5 per year of attained age of the tree, brought about only a slight increase in yield, and that was first observed in 1946. However, as was the case with potassium, the higher levels of phosphorus tended to make the use of nitrogen more effective. The greatest yields resulted when the high levels of all three elements were used together.

Bahrt and Potter (2) have reported on an experiment at Lucedale, Mississippi, similar in design to that reported here, but one in which the differences in levels of nitrogen, phosphorus, and potassium were considerably smaller. At Lucedale, 0.51 pound of nitrogen per tree per year improved 4-year average yields by 9 pounds of air-dry fruit per tree, which was a higher percentage increase than that reported here. No direct effects of phosphorus or potassium on yield and no significant interactions were observed at Lucedale, where for various reasons the degree of precision attained was somewhat lower than that in the experiment at Bush, Louisiana. In general the effects of nitrogen, phosphorus, and potassium on fruit composition in the Lucedale orchard were similar to those reported here.

The percentage of oil in the whole air-dry fruit was increased by the high level of nitrogen in the case of the 1944 crop, and by potassium in the crops of 1944 to 1946. The increase in yields of fruit and in oil in the whole fruit resulted in increased total production of oil for the crops of 1944, 1945, and 1946 from 20.21 pounds per tree at the low level of nitrogen fertilization, to 28.66 pounds per tree at the high level of nitrogen, and from 22.68 pounds per tree for the low level of potassium to 26.31 pounds per tree at the high level of potassium fertilization. The total increase for the three years following the application of the high levels of both nitrogen and potassium was 12.08 pounds of oil per tree over that produced by plots receiving the low levels of these two elements. With 70 trees per acre, the average annual production of oil resulting from the use of the high level of both nitrogen and potassium, was equivalent to 282 pounds per acre.

The trees receiving the high level of potassium were 27.0 square centimeters, or 9.39 per cent, larger at the end of the 1946 growing season than trees at the low level of potassium. Trees receiving both the high level of nitrogen and the high level of potassium were 99.2

square centimeters, or 38.39 per cent, larger at the end of the 1946 growing season than trees at the low level of both these elements.

The practice of fertilizing cover crops in tung orchards with 40 pounds of P_2O_5 per acre, in the form of basic slag or superphosphate, and 20 pounds of K_2O, as muriate of potash, is fundamental in a sound fertilizer program. Under average conditions in Mississippi and Louisiana the application of 0.16 pound of N and 0.12 pound of K_2O per year of attained age directly to the tree in early spring, is fully justified. In view of the results reported here, 0.08 pound of P_2O_5 per year of attained age applied directly to the trees with the nitrogen and phosphorus, would probably be profitable. It is expected that the benefits from these applications will be cumulative, and will continue until such time as the trees become so large that crowding of tops or roots or both prohibits further increase.

Summary

In an extensive experiment in which tung trees were supplied with three levels of each of three elements, nitrogen, phosphorus, and potassium, over the period 1943 to 1946, yields were increased most promptly and to the greatest extent through the use of nitrogen; but ultimately highest yields were obtained where nitrogen was used in combination with potassium and phosphorus. Increased yields were associated with greater growth of trees, increased number of shoots, and a higher number of pistillate flowers per terminal bud.

Oil in the kernel tended to be decreased by the use of nitrogen and increased by the use of potassium. The percentage of kernel in the whole fruit was increased by both nitrogen and potassium. The net result was a substantial increase in oil in the whole fruit where nitrogen and potassium were used.

The application of nitrogen, phosphorus, and potassium were promptly reflected in increased percentages of the respective elements in the dry weight of the leaves. The magnesium content of the leaves tended to be in inverse ratio to the potassium content.

A very interesting and important relation was observed between the potassium content of the leaves and the rate of application of nitrogen. When a high level of nitrogen was used in combination with a low level of potassium, potassium in the leaves declined steadily over the 4-year period and by 1946 had dropped to a level close to the deficency stage. Where ¾ pound of K_2O was used in combination with each pound of N applied, a slight decline in the potassium content of the leaves was observed. Only where potassium was applied at a high level in combination with nitrogen at the low level, was the original potassium content of the leaves fully maintained.

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Further Work on Leaf Nitrogen and Leaf Color as Measures of the Nitrogen Status of Fruit Trees

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THIS paper summarizes representative data on the usefulness of leaf color and leaf nitrogen measurements that have accumulated since our preliminary reports (1, 2).

PROCEDURE

Median shoot leaves were taken at random from the outsides of the experimental trees, at a convenient height. In the apple and prune orchards a separate sample of 30 leaves was taken from each tree; in the peach orchard a 30-leaf sample was taken from each block of six trees. A disk 16.6 mm in diameter was cut from each leaf. The 30 disks comprising a single chlorophyll sample were immersed immediately in methyl alcohol, or, when that was not available, in 95 per cent ethyl alcohol, and the sample jars were stored in the dark until the chlorophyll determinations were made. Chlorophyll extractions were completed within a week of sampling, in a darkened laboratory, and the extract was read in a photo-electric colorimetric according to the procedure of Compton and Boynton (1). The colorimetric readings were calibrated on the basis of chlorophyll extracted from fresh McIntosh apple leaves according to the AOAC method (4). Calibration curves were made also for chlorophyll extracted from fresh Italian prune and Elberta peach leaves. The curve for Italian prune was substantially the same as for McIntosh apple and no correction factor was used for the prune leaf samples. The Elberta peach chlorophyll curve differed to the extent that a correction factor of 0.9 was used for the Elberta leaf samples.[1] The leaf samples remaining after chlorophyll disks were removed were dried and subsequently analyzed for total nitrogen by the Kjeldahl method.

RESULTS

Shannon McIntosh Apple Orchards:—Fig. 1 shows seasonal trends of total nitrogen and chlorophyll in leaves from McIntosh apple trees under three levels of nitrogen fertilization over a 4-year period in which weather and crop varied greatly. There were 16 randomized replications of each treatment. In this orchard ammonium sulfate was broadcast in early April annually from 1942 under the tree branches at the following rates: 7½ pounds (H), 5 pounds (M), and 2½ pounds (L). The figure shows characteristic downward trend of total nitrogen concentration for all treatments and years. The percentages at any date were highest for leaf samples from treatment H and lowest for leaf samples from treatment L, but there was rather great variation from year to year among samples taken from the same treatment and about the same time. The seasonal curves for chlorophyll show char-

[1]This work will be reported separately by C. R. Gross, who undertook it.

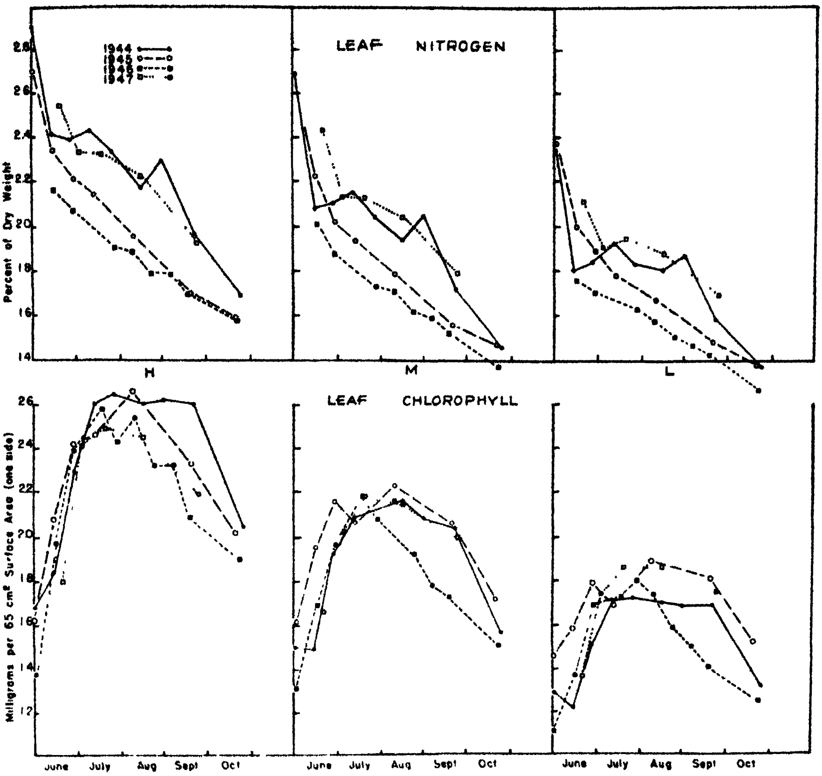

FIG. 1. Seasonal variations of leaf nitrogen and chlorophyll in a McIntosh apple orchard under three nitrogen fertilizer treatments over a four-year period.

acteristic midsummer maximum levels preceded and followed by lower chlorophyll levels, in all treatments and years. The chlorophyll content was highest at any date in leaf samples from treatment H and lowest in leaf samples from treatment L. While there was variation in the chlorophyll concentrations from year to year among samples taken from the same treatment and about the same time, it was somewhat less than the variation in nitrogen particularly in treatment M. Correlation between total nitrogen and chlorophyll in the samples of any date was very high, the coefficient (r) ranging between 0.80 and 0.95. But the regression of chlorophyll on nitrogen varied considerably, and the direction and slope of the nitrogen and chlorophyll curves changed throughout the season.

The trees of treatment M gave yields close to maximum and fruit color intermediate between the H and L treatments and appeared to be the most desirable nitrogen status; cholorphyll content between 2.0 and 2.2 mg per sample with 65 cm^2 area on one surface and nitrogen between 1.73 and 2.12 per cent of dry weight occurred in leaf

samples taken in July from the M treatment. In 1946 total nitrogen was lower for all treatments than in the other three years. This may have been the result of very heavy leaching rain throughout the growing season. It was associated with earlier decrease of leaf chlorophyll in the M and L treatments following the July peak, than in the other years, and this was correlated, in turn, with better color of the fruit sample from treatment M than in other years with no significant difference in fruit color among the three treatments.

Sodus Fruit Farm McIntosh Apple Orchard:—Fig. 2 shows the seasonal trends of total nitrogen and chlorophyll in leaves from a McIntosh apple orchard for the first year under differential nitrogen fertilization with urea broadcast on the ground in April, and in sprays at 5 pounds per 100 gallons (3). There were three rates of ground application in single tree blocks replicated 20 times: none (treatment F), 1.5 pounds (treatment B), and 3.0 pounds (treatment E). There were three spray treatments, at 2-week intervals starting a few days after petal fall, 20 gallons per tree per application: three sprays (treatment A), six sprays (treatment C), and three sprays in addition to

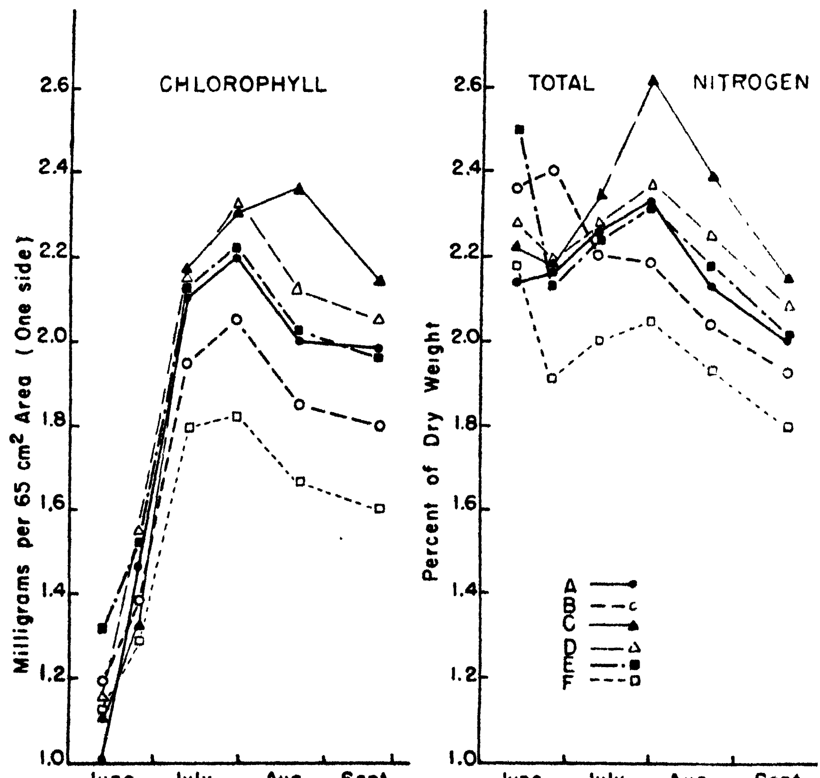

FIG. 2. Leaf chlorophyll and nitrogen in McIntosh apple leaves from trees under various urea spray and nitrogen fertilizer treatments (1947).

1.5 pounds ground application. In terms of nitrogen applied, spray treatment A was equivalent to ground treatment E (3 pound urea), ground treatment B was half treatments A (or E), spray treatment C was twice treatments A (or E), with combined spray and ground treatment D intermediate between treatments C and A (or E). It will be seen in Fig. 2 that leaf chlorophyll and nitrogen levels at the end of the growing season corresponded with the total amount of nitrogen applied in one way or another. It is also apparent that treatment C, six urea sprays the last of which was in August caused a sharp increase in leaf nitrogen, in opposition to the normal seasonal decrease, raising and prolonging the peak of chlorophyll content. It is probable that the relatively high chlorophyll level at the end of the growing season in leaves from all plots, and the slight increase of total nitrogen in leaves from treatments other than C were due to the fact that the row middles were disked several times in July to eliminate deep ruts that had developed in the spring.

Yields were low in 1947 in this orchard due to poor pollination, and there were no significant differences associated with treatment. Fruit color was best for samples from the unfertilized F trees, worst for the C trees, with the A and B treatments showing a slight advantage over D and E. Terminal growth was least for the F trees and most for the C, D, and E. More work is needed to find the optimum nitrogen program in this orchard but the relationships of leaf color and nitrogen to economic responses are clearly evident, and the ranges of concentrations are similar to those found in the Shannon orchard.

The results in these McIntosh orchards tend to support the tentative suggestion that a leaf chlorophyll level of 2.0 to 2.2 mg per 65 cm^2 surface (one side) in midsummer, corresponding to color standard 4 (2) is associated with nitrogen status of spring fertilized trees high enough for maximum yield; greater chlorophyll content at that time may indicate nitrogen status above that necessary for maximum yield, with unnecessary reduction of fruit color at harvest time; less chlorophyll in that period may reflect nitrogen status so low as to have reduced the potential yield. Nitrogen percentage in the leaves during the midsummer period between 1.9 and 2.1 was frequently associated with leaf color in the range of standard 4, but this was not always the case. The late application of urea sprays was accompanied by marked increase of leaf nitrogen and chlorophyll of diagnostic value.

Green Italian Prune Orchard:—Fig. 3 shows the seasonal trends of total nitrogen and chlorophyll in leaves from an Italian prune orchard for the first year under differential nitrogen fertilization. Nitrogen was applied as ammonium sulfate at four rates: none (treatment A), 2½ pounds (treatment B), 5 pounds (treatment C) and 15 pounds (treatment D). The orchard was in non-leguminous sod. There were 20 randomized replicates for each treatment. The seasonal trends were similar to those for McIntosh apple leaves. At any date, the chlorophyll and total nitrogen levels were directly correlated with fertilizer treatment. But the actual levels were greatly different from those in McIntosh apple leaves; chlorophyll concentration was much lower, and total nitrogen was much higher. Correlation of these meas-

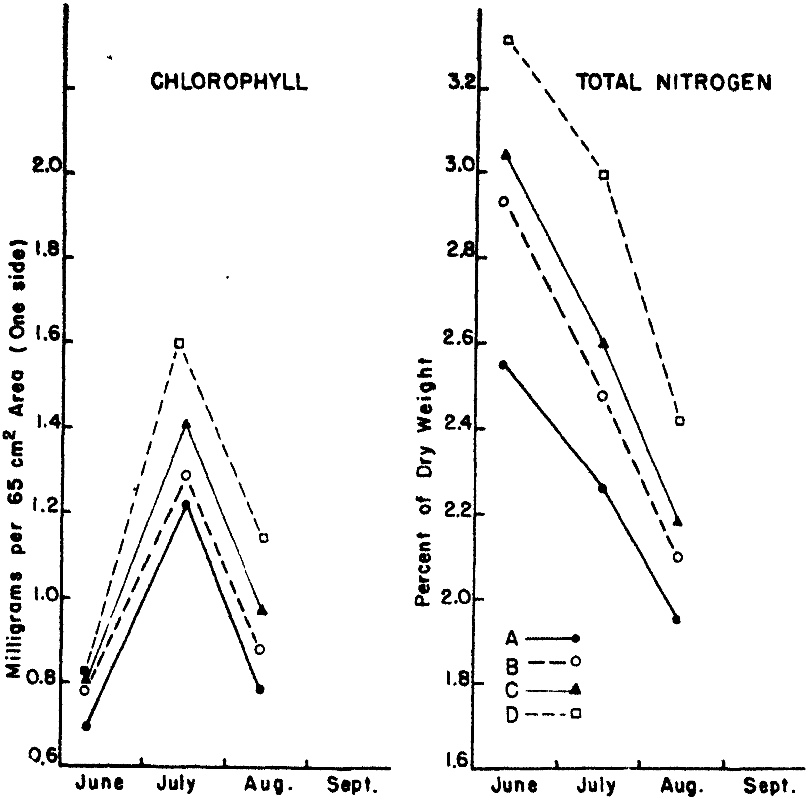

FIG. 3. Leaf chlorophyll and nitrogen in Italian prune leaves from trees under different nitrogen fertilization (1947).

urements with growth and yield responses over a period of years is needed in this and other prune orchards before they may be useful in diagnosis or prognosis.

Elliot Elberta Peach Orchard:—Fig. 4 shows the seasonal trends of total nitrogen and chlorophyll in leaf samples taken from an Elberta peach orchard in which two rates of nitrogen application (H and L), and two cultural systems (C and R) were maintained in various combinations. There were four replications of each treatment, in blocks of six trees surrounded by guard trees. The basic rate of nitrogen (L), 0.3 pound was broadcast on the orchard floor in the form of 5–10–5 in early April. The H blocks received, in the form of ammonium sulfate, additional applications of 0.4 pound nitrogen per tree on May 14, and 0.3 pound nitrogen on July 2, or a total of 1.0 pound nitrogen per tree in comparison with 0.3 pound for the L blocks. In the R blocks, the last cultivation was on June 7 at which time rye grass was seeded. In the C blocks, the last cultivation was on June 30, and no cover crop was seeded. There were marked differences in growth and in the peak

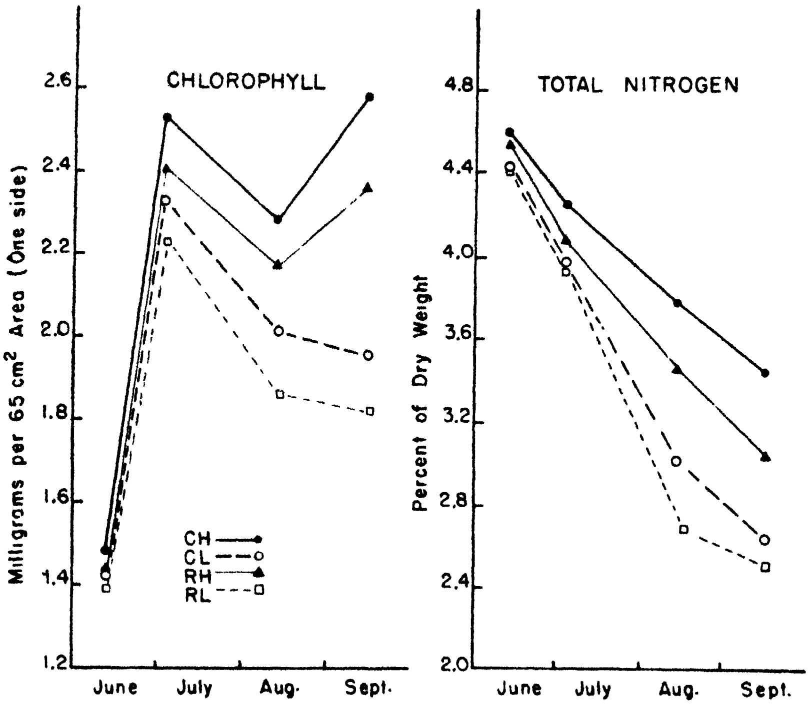

FIG. 4. Leaf chlorophyll and nitrogen in Elberta peach leaves from trees under different soil management and nitrogen fertilization (1947).

dates of harvest in the two extreme treatments, R–L blocks having the least growth and earliest harvest peak, and C–H blocks having the greatest growth and latest harvest peak. The seasonal trends of leaf total nitrogen and chlorophyll for the four blocks in general are similar to those in the three previous figures. The effects of soil management and fertilization on the levels of chlorophyll and nitrogen are also clearly apparent. The levels of chlorophyll and total nitrogen are different from those found in the apple and prune plots. As in the case of the prune data correlation of these measurements with growth and yield responses over a period of years must precede their use for diagnosis.

SUMMARY

These data on seasonal changes of chlorophyll and nitrogen in apple, prune, and peach leaves under different nitrogen fertilizer programs clearly indicate their usefulness as indices of nitrogen status. Leaf color determinations seem to be particularly useful in this regard. Enough data have accumulated on the seasonal fluctuation, and general range of values for McIntosh apple to permit the setting up of standard values for use in New York; this is not yet true for Italian prune and Elberta peach.

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Foliar Diagnosis: The Mineral Nutrition of Peach Trees With Particular Reference to Bacterial Leaf Spot[1]

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THIS is a continuation of the investigations reported last year (9, 10) in a commercial peach orchard in York County, Pennsylvania, in which many of the varieties, particularly Sunhigh, Summercrest, Goldeneast, and Hale are infected in varying degrees within and among the varieties by *Bacterium pruni*.

The orchard is situated on a hillside on a Chester silt soil, very low in organic matter. The soil is very shallow, solid rock being encountered 5 inches below the surface at many places.

The earlier exploratory study (10) was conducted with buffer trees between treated trees in a potash fertilizer experiment of two varieties, Sunhigh and Summercrest. One of the results brought out was that the values for the minor elements boron, iron, molybdenum and also sulfur were within the recognized critical limits for the age and type of leaf used. For this reason it appeared to be unnecessary to consider these elements further. But inasmuch as there was some question with respect to the manganese limits, examination for this element was made again. The zinc-containing sprays used by the grower made the determination of this element unnecessary.

The present investigation included trees of three varieties, Sunhigh, Goldeneast, and Hale from each of three rows, which in addition to the basic fertilizer, 600 pounds of 10–10–10 per acre in the spring of 1946 and previously from 200 to 300 pounds of 10–6–4 to the acre each year, were differentially treated with 0, 5, 10, and 15 pounds of muriate of potash per tree. Three trees in each row received the extra potash in the fall of 1945 and three in the fall of 1946.

NUTRITION AS A POSSIBLE FACTOR IN LEAF SPOT

Several excellent monographs relating to bacterial leaf spot of peach have been published (1, 3, 7). Hopperstead and Manns (3) observed that trees of moderate vigor were less susceptible to attacks of *Bacterium pruni* than were trees of extremely low or of high vigor; this conclusion was deduced from the observations that the disease is of greatest concern in regions where the soil is of low fertility and the trees, as a result, are lacking in general vigor, or where the general vigor is extremely high because of applications of excessive quantities of nitrogen as when trees have been heavily pruned; and that moderately vigorous trees in desirable situations suffer less even though they are actually infected. With respect to susceptibility in relation to age of trees, Hopperstead and Manns (3) consider that succulence rather than age of the trees is the predominant influence. Their efforts were concentrated upon eliminating the disease from infected stock by growing them under the dry conditions of the greenhouse and with

[1]Authorized for publication on August 28, 1948 as paper No. 1466 in the Journal Series of the Pennsylvania Agricultural Experiment Station.

sub-irrigation or by growing them in arid regions.

The first investigator to consider nutrition in relation to the disease was Poole (6) who was able to effectuate control of the disease in 12-year-old Elbertas by spraying the trees with sodium nitrate every 2 weeks, a treatment which resulted in a much higher content of potassium, calcium, and magnesium and also of iron. These facts suggest that an increase in our knowledge of the mineral nutrition of healthy and diseased trees would be a profitable line of approach. If the problem is associated with optimum nutrition, there exists a paucity in our knowledge of the standard values for even the major elements in peach trees.

Optimum Nutrition of Fruit Trees Less Well-Defined Than for Herbaceous Plants

In comparison with that in herbaceous plants the determination of this optimum is more elusive; for even though yields of fruit can be taken as an index of the general vigor, in fruit trees the nutrient elements stored in the branch growth complicate the determination of the relationship of leaf composition to yields. This is particularly true with such an extremely mobile element as potassium, inasmuch as it is much more difficult to determine if luxury consumption of this element occurs. These difficulties are now well recognized and are discussed by Lilleland and Brown (4, 5) in their comprehensive surveys of the potash status of peach trees in California orchards.

Experimental

The samples were taken at three periods from the middle of the terminal growths on June 18, July 16, and August 6, 1947. Each leaf was brushed with cheesecloth immediately on removal from the tree. About 25 leaves, including the petioles constituted a sample. These were dried and ground in the usual manner (8).

Table I shows the amounts of additional potash applied to each tree, the yield of fruit, and field notes on the condition of the trees together with certain analytical data on the composition of the leaves described and discussed later.

Fig. 1 shows the course of nutrition, that is, the percentages of nitrogen, phosphoric acid, potash, lime and magnesia in the leaves at each period of sampling. Fig. 2 shows the deviation of the leaf composition of each tree from the tentative optimums for nitrogen, phosphoric acid, and potash and their relation to yields.

Discussion of Results

First considering the field data as given in the last three columns of Table I, it is apparent that a consistent relationship between the amounts of potash added and yields does not exist, whereas there is a good correlation between vigor and defoliation; the higher the vigor the less the defoliation.

Turning to the laboratory data (Fig. 1) showing the relationship of supply to and demand by each tree for the several elements, it will be

TABLE I—NUTRITIONAL STATUS OF THREE VARIETIES OF PEACH TREES IN RELATION TO BACTERIAL LEAF SPOT

No.	N (Per Cent)	P_2O_5 (Per Cent)	K_2O (Per Cent)	CaO (Per Cent)	MgO (Per Cent)	Intensity of Nutrition (Per Cent)	NPK-Units	Yield of Fruit (Bushels)	Extra KCl Added (Pounds)	Field Notes August 6, 1947
							Sunhigh			
F6	3.12	0.546	3.15	3.20	0.721	6.82	70.43:8.12:21.45	7.25	15	Relatively vigorous
J6	3.23	0.475	2.54	3.18	0.74	6.24	75.56:6.55:17.89	5.79	5	20 per cent defoliation, relatively vigorous
N6	3.09	0.466	2.60	2.88	0.64	6.16	74.56:6.67:18.77	4.00	15	30 per cent defoliation, medium vigorous
H6	3.12	0.483	2.38	3.44	1.00	5.98	75.71:6.92:17.37	3.38	0	50 per cent defoliation
L6	2.79	0.438	1.90	2.73	0.71	5.13	77.17:7.16:15.67	2.50	10	Sickly, bacterosis of fruit, 80 per cent defoliation
							Goldeneast			
J9	3.35	0.493	2.79	3.25	0.71	6.63	75.07:6.44:18.49	6.50	5	20 per cent defoliation, relatively vigorous
L9	3.13	0.461	2.86	3.02	0.62	6.45	73.44:6.38:20.18	4.50	10	30 per cent defoliation, bacterosis of fruit
N9	3.24	0.458	2.75	2.68	0.67	6.45	74.77:6.22:19.01	4.50	15	40 per cent defoliation, relatively vigorous
H9	3.28	0.470	2.66	3.17	0.73	6.40	75.72:6.39:17.89	3.75	0	40 per cent defoliation, medium vigorous, bacterosis of fruit
							Hale			
J17	3.36	0.522	2.48	3.37	0.76	6.36	76.19:6.96:16.85	6.63	5	20 per cent defoliation, relatively vigorous
N17	3.25	0.510	2.62	3.41	0.68	6.38	74.83:6.94:18.23	4.88	15	20 per cent defoliation, medium vigorous
H17	3.30	0.519	2.38	3.34	0.74	6.20	76.37:7.09:16.54	4.75	0	30 per cent defoliation, medium vigorous
L17	2.88	0.452	2.41	2.62	0.64	5.74	74.08:7.38:18.54	2.88	10	40 per cent defoliation, fairly vigorous
D17	2.29	0.443	1.66	1.78	0.420	4.39	74.72:8.52:16.76	A few very small fruit	10	Very little foliage, very low in vigor

noted that whereas in all cases the contents of nitrogen and phosphoric acid are lower at the last period than at the first period of sampling, the situation is reversed in the case of the potash graphs; here the values are higher at the last then in the first period except for the highest yielding tree F6.

It is known that the developing fruit makes a high demand on the phosphoric acid and potash. We should expect, therefore, particularly in the trees which did not receive additional potash, that the slope of the graphs for potash would be downwards and not upwards. Apart from this influence of fruit, normally the leaf content of the mobile elements nitrogen, phosphorus, and potash decreases with maturity, although this decrease is not always progressive throughout the cycle. The conclusion to be drawn is that potash is not well utilized except

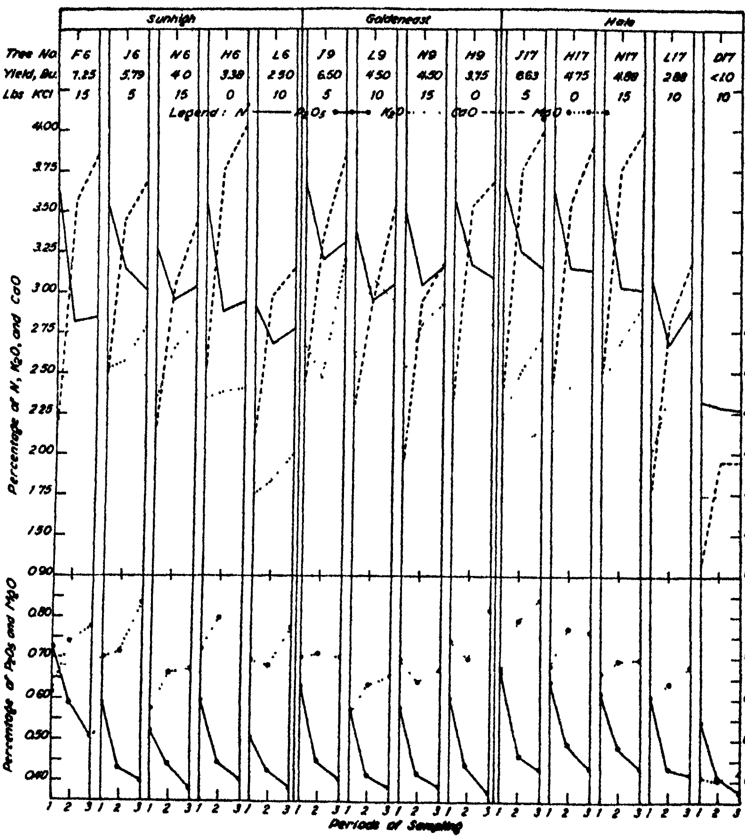

FIG. 1. Percentages of N, P_2O_5, K_2O, CaO, and MgO in dried leaves at the different periods of sampling, from peach trees of three varieties, Sunhigh, Goldeneast, and Hale, differentially fertilized with muriate of potash, arranged in descending order of yields within each variety, from left to right.

in the highest yielding tree F6. Inasmuch as the interaction of nitrogen, potash, and phosphoric acid is a firmly established physiological fact, the indications are that a proper balance among the three elements is lacking in all trees except the highest yielding tree F6.

Inasmuch as in most cases the nitrogen graphs are reversed in direction during the last period, whereas those for phosphoric acid continue their descent, the evidence is that phosphoric acid is too low in relation to the nitrogen in all cases except that of tree F6. This conclusion is supported from an inspection of the graph (not shown) in which the nitrogen is plotted against phosphoric acid.

Nitrogen:—At the first sampling nitrogen is at relatively high levels (3.66 to 3.68 per cent) in the three highest yielding and relatively most vigorous trees F6 (yield 7.25), J17 (yield 6.88) and J9 (yield 6.5). But very high nitrogen contents (3.67 to 3.69 per cent)

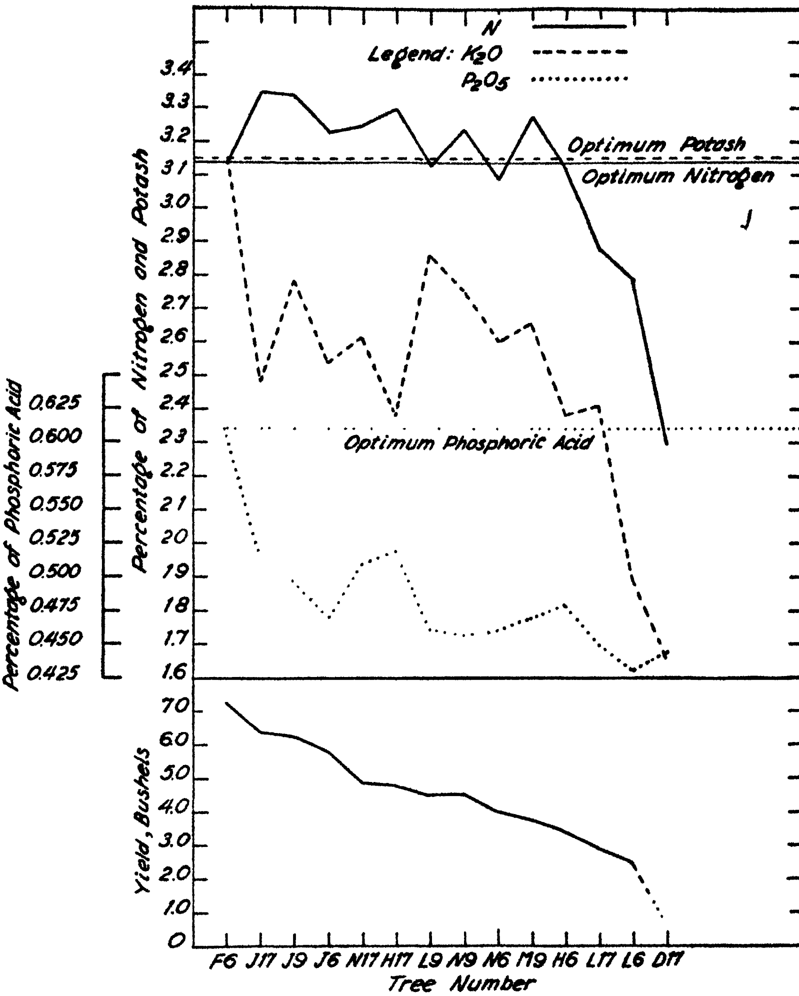

FIG. 2. Mean percentages and tentative optimum percentages of N, P_2O_5, and K_2O of dried leaves for three periods of sampling, together with yields of the respective trees, in dscending order from left to right.

also occur at this date in N17, and two other trees not indicated in the figure having somewhat lower yields (4.5 to 4.75).

In the two low yielding trees L17 (yield 2.88) and L6 (yield 2.50) the nitrogen level at the first sampling is much lower (3.09 per cent and 2.92 per cent respectively), and in the very sickly tree D17 the nitrogen content is reduced to 2.32 per cent at this first period. In these trees of low vigor the slope of the nitrogen graphs is relatively small, indicating that demand relative to supply is low even at the relatively low level of supply. The contents of nitrogen at the first

sampling of the remaining trees with intermediate yields are between those of the trees of high and low vigor.

Although, then, there is no consistent relationship of nitrogen even at the first sampling to yields of fruit, a relatively high content of this element is associated with high yields, and a relatively low content with low yields. It is obvious from an inspection of the steepness of the slopes of the graphs for nitrogen that the greatest demand for this element is during the period up to and including the second sampling on July 16, after which many of the graphs reverse in direction. The slope is steepest in F6.

Potash:—At the first date of sampling the content of potash (3.21 per cent) is highest of any in the tree F6 having the highest yield. In this case the steepness of the slope of the graph is small and, as already mentioned, in contradistinction to that of all the other trees, is downward (and not upwards) indicating in the case of F6 that demand by the younger leaves is greater than the supply to the leaf of this rank even at the high level of supply. This tree was one that received 15 pounds additional muriate of potash in November, 1945.

The contents of potash in the next three highest yielding trees, J17, J9, and J6 at this first sampling are very much lower — namely, 2.22, 2.68, and 2.27 per cent, respectively, but reach with continued ascent of the graphs the values 2.71, 3.19, and 2.78 per cent at the last sampling, and in the tree J9, the content of potash at the last period is higher than that of F6.

No consistent relationship exists between the leaf content of K_2O and the amount of this element applied, although among the trees of relatively high or moderate vigor, those which received an additional 5 pounds of muriate have a higher leaf content than those which did not. Trees of poor vigor are low in potash even when receiving an additional amount of 10 pounds. As with nitrogen, therefore, a relatively high content of potash is associated with the better yields, whereas a low content is accompanied by low yields.

Phosphoric Acid:—In all cases the slope of the graphs is progressively downwards with increase in maturity of the leaf. At the first sampling the highest-yielding tree has the highest content (0.730 per cent) of phosphoric acid, and this lead is maintained throughout the whole period. Although at this period the next highest yielding tree J17 has the second phosphoric acid content, the relationship of the content of this element to yields thereafter breaks down, with H17 (yield 4.75) having the third highest, J9 (yield 6.50) fourth highest, and J6 (yield 5.79) seventh highest yield. In general these relationships hold throughout the cycle.

As is the case with nitrogen and potash, the trees L17, L6, and D17 which are low in vigor have also the lowest content of phosphoric acid. Here again the trees of high vigor are sharply separated in their phosphoric acid content from those of low vigor, with no consistent relationship among trees between the highest and lowest in yields.

Lime:—The increase in the content of calcium with maturity of the leaf is a characteristic of this element of low mobility and in all cases the increase is progressive in successive samplings.

Magnesia, in general, also increases with maturity of the tree, although in one tree (N9) the content of MgO is lower at the last sampling than at the first, for which fact the reason is not apparent. At the first sampling CaO is relatively low (2.18 per cent) in the highest yielding tree F6, which has the highest potash content at this date. This influence of calcium in reducing the potash content is apparent in other trees particularly at this first sampling.

Although the very sickly tree (D17) has a very low CaO content, namely 1.31 per cent, there appears to be no consistent relationship of the calcium content to yields or vigor in the trees of relatively high and medium vigor.

Magnesia:—The poorest tree (D17) has a very low MgO content during the whole period (range 1.31–1.96), whereas the other trees low in vigor and L6 have as high MgO contents as the highest yielding tree (F6), and at some periods even higher, nor is any relationship to defoliation to be observed.

It is of interest to note that, thus far, there is no evidence that the relatively high additions of potash have reduced the MgO contents to critical values.

The Resultant Values for the Fertilizer Entities

Another method of examining the data is to consider the resultant values for each element during the period of observation in relation to growth and development (8). The resultant or mean values are given in columns 2, 3, 4, 5, and 6 of Table I and shown in Fig. 2. The data for a particular tree, therefore, represent an integration of all the factors operating to affect the content of nitrogen, phosphoric acid, and potash during the period of sampling. The horizontal lines in Fig. 2 represent for potash, nitrogen, and phosphoric acid respectively reading downwards the tentative optimum values for the peach.

The values for N, P_2O_5, and K_2O of the highest yielding tree (F6) have been taken as the tentative optimums. Suggestions for obtaining standard values and for their use are discussed in an interesting and exhaustive monograph by Goodall and Gregory (2). As they point out, these standards should be obtained from an extensive and sound series of field trials. Based on this criterion the standard values proposed here must be regarded as preliminary only, and from the foregoing discussion it would appear that in the case of fruit trees approximations only can be expected. The loci of the percentage values for nitrogen, phosphoric acid, and potash respectively for each tree have been joined; the loci of the individual yields also are joined. The resulting graphs give a picture from which one can readily follow the variation in the content of the several entities (elements) in relation to the yields and also their relative divergence from the tentative optimums represented by the horizontal lines.

The general trend of the graphs indicates a decrease in the contents of each of the elements with reduction in yields. But this reduction in the content of an element is not regularly progressive as yields decline. Wide fluctuations occur particularly in the potash contents. For example, a sharp rise (equal to nearly one-half of 1 per cent) in

potash is in evidence in passing from H17 (yield 4.75 bushels) to L9 (yield of 4.50 bushels).

Much greater consistency with respect to the content of an element in relation to yields is apparent when each variety is considered separately. This relationship is particularly conspicuous when the values of the intensities of nutrition (per cent N + P_2O_5 + K_2O) are calculated. These are shown in column 7 of Table I. In Sunhigh the intensity is progressively reduced from 6.82 to 5.12 as yields drop from 7.25 to 2.50 bushels and in Hale the intensities are reduced from 6.26 to 4.40 as yields drop from 6.63 bushels to less than 1 bushel. In Goldeneast with a lower yield range (6.5 to 3.75) the reduction in intensities is relatively less. These results are in accordance with the theory that a high intensity of nutrition is a requisite for high yields.

The Qualitative Relations Between the Elements and Yields

In herbaceous plants a close correlations is found between the "foliar diagnosis values" (8) as represented by the intensity of nutrition and the *NPK-units* representing the proportions or balance of the three elements. In this experiment no consistent relationship of the *NPK-units* (given in column 8, Table I) to growth and development is shown. In the Sunhighs there is a marked difference in the "foliar diagnosis values" of the highest and lowest yielding tree; the high intensity of tree F6 is associated with an equilibrium having a relatively low value for nitrogen and high value for potash, and the low intensity of tree L6 with an equilibrium having a high value for nitrogen and low value for potash. For intermediate intensities and yields the values for the *NPK-units* also are intermediate, with little difference among them. In Goldeneast with a very small difference between the intensities of the highest and lowest yielding tree the differences in the *NPK-units* are relatively smaller. In Hale the relatively large difference in the intensities and yields of the highest and lowest yielding tree is not associated with any particular trend in the composition of the *NPK-units.*

One of the difficulties in relating nutrition to response in fruit trees is that of obtaining an adequate index of performance. Yields are essentially related to the size of the tree which in turn depends on the degree of pruning. Unless all trees are pruned exactly to the same relative extent variations in yield will occur on this account. So apart altogether from intrinsic variations due to seedling stocks there is an undetermined error associated with nutritional investigations in commercial peach orchards.

Manganese:—The possibility that the content of manganese might be a factor in leaf spot again was examined. The range for the first sampling on June 1 was found to be from 45 to 81 micrograms per gram; no relationship to vigor or defoliation was apparent.

Chlorine:—The question of chlorine toxicity was considered also a possible factor, inasmuch as relatively large quantities of KCl were applied. The values were found to be normal (range 0.082–0.090 per

cent Cl). There was no relationship between the amount of KCl applied and the chlorine content of the leaves.

Summary and Conclusion

Further studies were made on the course of nutrition during the growing season, with respect to the nutrient entities nitrogen, phosphoric acid, potash, lime and magnesia, on peach trees of the varieties Hale, Sunhigh, and Goldeneast in a commercial orchard which were infected in different degrees by *Bacterium pruni* and which had been fertilized differentially with muriate of potash during the two preceding seasons, in addition to fairly generous uniform applications of complete commercial fertilizer.

An attempt was made to ascertain the relationships among the degree of infection, the vigor of the trees, the yields, and the course of nutrition with respect to the several entities as well as the derived foliar diagnosis values, and also to assign optimum values with respect to the major nutrient entities.

It is pointed out that defoliation by bacterial leaf spot was inversely related to vigor, which in turn was directly related to yield. No relation was found between the course of nutrition with respect to potash and the potash applied; in the leaves from the most vigorous tree, which showed the least damage from leaf spot, the content of potash was highest at the first sampling, and in the trees of low vigor the potash content of leaves also was low.

In general, the vigor and yield of the trees are found to be directly related to the intensity of nutrition, and this relation is more consistent if the varieties are considered separately. No relation was found between vigor and the equilibrium among nitrogen, phosphoric acid, and potash, expressed as *NPK-units*, although the highest yielding tree had the lowest proportion of nitrogen and the highest of potash in the composition of the *NPK-unit*.

Evidence is presented which indicates that the phosphoric acid in the leaves of most of the trees studied was too low in proportion to the nitrogen, and both nitrogen and phosphoric acid were low in proportion to potash in the trees lowest in vigor. The latter relationship resulted in faulty utilization of potash and the accumulation of this element in the leaves as the season advanced.

None of the elements examined, including manganese and chlorine, approached concentrations reported by other investigators to be critical, with respect either to deficiency or to toxicity.

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Color As An Index of Nitrogen Content of Leaves of York and Stayman Apples

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IMMEDIATELY following the preliminary report by Compton and Boynton (1) of a leaf color chart for estimating the nitrogen content of McIntosh apple leaves, it was decided to determine whether such a system would apply to some of the most widely grown varieties of apples in Virginia. The two varieties available for this study were 34-year-old York and Stayman trees in the experimental orchard at Blacksburg. As the newly developed color standards (2) were not available in 1945, an attempt was made to use the color charts of Maerz and Paul. It was found that the greens on these charts did not match apple leaf color closely enough to be used. With the appearance of the new standards in 1946 these were used in estimating the nitrogen content of leaves of the above named varieties. The estimates were compared with the nitrogen analysis of the leaves and with fruit yield, color, size, and quality in storage.

Previously, overall tree color, measures of trunk growth rate, and estimates of shoot or spur growth have been the most practical methods of arriving at an evaluation of tree vigor and as indications of probable future fruitfulness. It is generally conceded that the foregoing methods are not sufficiently precise for accurate determination of the nutritional level of the tree. Terminal shoot growth is highly variable depending on height in the tree and the angle that shoots make with the horizontal plane. Within reach of the ground, considerable variation is to be found in the annual elongation of both shoots and spurs.

As certain weaknesses seem evident in the nitrogen level index based on leaf color, considerable judgment may be required in the application of such determinations. Shear (4) has demonstrated the effects of ferric dithiocarbamate in increasing the chlorophyll content of birch foliage affected with an iron-deficiency-induced chlorosis. Moreover, the black color of this fungicide might have the apparent effect of intensifying the green color. Dichloronaphthoquinone is said to decrease leaf color. In addition to these spray chemicals, others now in use or which may be discovered in the future may lighten or darken leaf color. The effect of the intensity of sunlight which varies with elevation and atmospheric conditions is a possible factor. A number of other excesses or deficiencies may further affect the quality of leaf color.

For a period of several years the orchard available for this study had been maintained at a low level of fertility. Trees as similar in appearance as possible were selected on the basis of uniformity of yield. Four replications of one tree each for each variety were chosen for each nitrogen fertilizer treatment, which was applied about 1 month in advance of blooming date. Sodium nitrate is being used as the source of nitrogen in this study. In 1945, it was used at the rates of 2.5, 5.5, 8.5, and 11.5 pounds per tree. In 1946, a fifth treatment of 14.5 pounds was included. Since the differences between the 3-pound

increments of fertilizer were too small to measure, another change was made in the spring of 1947. Trees that had been receiving 5.5 pounds of fertilizer were given 20.5 pounds and those that had been receiving 11.5 pounds of fertilizer were given 26.5 pounds, giving 6-pound increments between fertilizer treatment in 1947 and 1948.

While Compton, *et al* recommended that leaves be selected from two-thirds of the way back on the current year's shoots, the authors have found that the leaves of non-fruiting spurs are just as satisfactory and are more uniform in age. Accordingly, 25 spur leaves from each tree have been used in each determination. Healthy leaves were picked from spurs well exposed to the light on representative limbs from all sides of the trees. Leaves were selected at heights within reach from the ground. During a single year leaf samples of the two varieties were collected within a period of 2 days. Sampling dates for the different years varied as much as a month, starting July 1. Leaf color readings were made from each leaf within a period of 2 to 3 hours after the leaves were picked since it was found that Stayman leaves started turning brown several hours after picking. If the leaves were bruised, they would turn brown in a few minutes. Once the leaves were discolored, the color chart could not be used. It was found that the color comparisons were made more easily if the color standards were coated with a thin film of paraffin which produced a gloss similar to that of most of the leaves.

The mean color for each 25 leaf sample was determined and an estimated nitrogen value obtained from the table accompanying the color chart. These leaves were then dried and ground and a composite sample from each lot analyzed for total nitrogen by the method described by Lindner (3).

A representative sample of 1 bushel of fruit was picked from each quadrant of the tree when yields were being taken. This 4-bushel sample was graded for color and size. A 2-bushel sample was selected for the observations on keeping quality in common storage. During the storage life of the fruit the samples were graded at intervals to determine the numbers of fruit showing tissue breakdown deeper and more serious than scald.

The range in the nitrogen analyses for 1945 was small and did not correlate well with the amount of nitrate supplied to the trees. For the Yorks the percentage of nitrogen in the leaves varied from 2.17 to 2.36 and for Stayman from 1.90 to 2.07 (Tables I and II).

The effect of the nitrate fertilizer on the nitrogen content of the foliage was more pronounced in 1946 with statistical significance showing between some treatments. During this period 3-pound increments of fertilizer were used.

In 1947 and 1948, using a wider range of 6-pound increments of sodium nitrate the correlation between applied nitrogen and total nitrogen in the foliage was greater than in 1946.

Comparison of the nitrogen found by analysis with that obtained from the table based on the color chart showed that the estimated values corresponded very closely with the actual analyses for Stayman leaves. In the case of York leaves the estimated values were too

TABLE I—PER CENT NITROGEN IN YORK LEAVES BY CHEMICAL ANALYSIS AND ESTIMATION FROM LEAF COLOR

$NaNO_3$ Per Tree (Lbs)	1945	1946		1947		1948	
	Analysis	Analysis	Estimated	Analysis	Estimated	Analysis	Estimated
2.5	2.21	1.99	2.42	2.19	2.20	1.96	2.01
5.5	2.17	1.99	2.50	—	—	—	—
8.5	2.30	2.35	2.84	2.27	2.44	2.43	2.58
11.5	2.36	2.21	2.90	—	—	—	—
14.5	—	2.48	2.90	2.32	2.38	2.52	2.66
20.5	—	—	—	2.74	2.82	2.59	2.81
26.5	—	—	—	2.80	2.82	2.74	2.89

TABLE II—PER CENT NITROGEN IN STAYMAN LEAVES BY CHEMICAL ANALYSIS AND ESTIMATION FROM LEAF COLOR

$NaNO_3$ Per Tree (Lbs)	1945	1946		1947		1948	
	Analysis	Analysis	Estimated	Analysis	Estimated	Analysis	Estimated
2.5	1.99	2.04	2.17	1.83	1.93	1.90	1.85
5.5	1.90	2.08	2.26	—	—	—	—
8.5	1.92	2.27	2.33	2.07	2.11	2.31	2.12
11.5	2.07	2.39	2.44	—	—	—	—
14.5	—	2.44	2.49	2.14	2.13	2.46	2.23
20.5	-	—	—	2.21	2.22	2.53	2.28
26.5	—	—	—	2.24	2.24	2.55	2.27

low showing that the same leaf color in York leaves indicated a higher nitrogen content than it did in the case of Stayman leaves. The estimated nitrogen values used for York leaves were scaled upward to correspond more closely to the actual analyses (Table III). The percentage of nitrogen represented by color standard 1 was raised from 1.5 to 1.7; for color standard 2, from 1.7 to 2.0; for color standard 3, from 1.9 to 2.3; for color standard 4, from 2.1 to 2.7; and for color standard 5, from 2.3 to 3.1.

TABLE III—ESTIMATED PER CENT OF FOLIAR NITROGEN BASED ON LEAF COLOR FOR YORK AND STAYMAN APPLE TREES

Color Standard	Per Cent Nitrogen		Color Standard	Per Cent Nitrogen	
	York	Stayman		York	Stayman
1	1.7	1.5	4	2.7	2.1
2	2.0	1.7	5	3.1	2.3
3	2.3	1.9			

The nitrogen content of York leaves was found to be higher than that of Stayman leaves.

Significant differences in yield, color, size, and breakdown of fruit did not occur in 1946 or 1947, and the data on these factors have not yet been obtained for 1948.

It is planned to continue this study until definite responses of the fruit to the nitrogen treatments are obtained. By that time the value of leaf color as an index of proper nitrogen fertilization of these two varieties of apples can be evaluated.

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Potassium Content of Various Parts of the Peach Tree and Their Correlation with Potassium Fertilization — A Sampling Study[1]

By D. E. H. Frear, R. D. Anthony, A. L. Haskins, and F. N. Hewetson, *The Pennsylvania State College, State College, Penn.*

A number of workers have demonstrated that the peach tree frequently suffers from potassium deficiency on certain soils (1, 2). The chemical analyses of various portions of the peach tree have shown that a relationship exists between the amount of potassium in leaf tissue and potassium supplied to the tree. The clearest demonstration of this relationship has been with trees grown in sand, and supplied with various levels of potassium, (3). This has led many investigators to study the practicability of using chemical analyses of various tissues as an index of the potassium nutrition in the peach, (4, 5). The leaf tissue is most frequently used for analytical studies of this kind, although other tissues, such as the leaf petioles, have been employed.

Although it is recognized that such variable factors as soil type, environmental conditions and varietal differences make it impractical to use tissue analyses as an absolute index of potassium deficiencies, it would be highly desirable to have a standardized analytical procedure available which could be used on occasion to furnish a general indication of potassium nutrition. For such investigations, analyses should be made on tissues in which there is the highest degree of correlation between potassium content and potassium supply. Apparently no systematic study has been made on the peach tree to demonstrate the degrees of correlation between these two factors in the various tissues of the tree. This is somewhat surprising, since it has been clearly shown that there is a considerable variation between the potassium content of old and young leaves on the same tree (5).

Purpose of the Present Investigation

The present study was designed to determine the correlation between potassium supply (as measured by a wide range of potassium applications) and potassium content (as measured by chemical analyses) in several parts of the growing peach tree. Leaves and woody tissue of several ages were analyzed on several dates over a 4-year period, as well as leaf petioles and fruit. No attempt was made to analyze the roots or older woody portions of the trees, as was done in our earlier work with apple trees (6), since such tissues are not available without seriously damaging or completely destroying the trees.

Experimental Procedure

Location and Fertilizer Treatments:—Three peach orchards located in different parts of Pennsylvania were used in this experiment.

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Preliminary samples were taken from the Harry Anderson orchard, located on a moderately deep phase of the Chester-Manor group of soils, between Stewartstown and New Park, in southeastern York County. Two varieties in this orchard, Hale and Hale Haven, had been fertilized with N, P, and K as follows: NP; PK; NNP; NPK; NPKK; and NNPKK. Each unit of N consisted of 1.5 pounds of commercial $NaNO_3$ per tree; P, 2.0 pounds of superphosphate per tree; and K, 1.5 pounds of commercial KCl, containing 0.75 pound K per tree. Differential treatments were begun in 1941, when the trees were in their fourth seasons; previous to this time uniform applications of N, P, and K had been given each tree.

The second orchard, designated as Benner, is located near Fairfield, in southwestern Adams County. This orchard was planted in 1940 with trees of the Elberta variety. The soil is a deep colluvial mixture of sandstones from the Dekalb series and igneous material from the Porters-Ashe series.

Differential fertilizer applications were begun in 1942, and a series of trees was treated with 1, 2, 3, and 6 units of potassium, applied to one group of trees as commercial K_2SO_4, and to another as KCl. The unit of K application was 0.37 pound K per tree. Nitrogen and phosphorus were applied uniformly to each tree in the block, and the potassium applications were made to duplicated 9-tree plots (3 x 3) within the block. The plots were randomized. This orchard has shown potassium deficiency symptoms, and is within one-fourth mile of the one described by Anthony and Dunbar (1).

A 4-acre block of Elberta and Belle of Georgia trees planted in 1934 in the college orchard, State College, Centre County, was used for the third experimental treatments. These trees were growing in Hagerstown silt loam, and were in good vigor at the time the experiment was conducted. Symptoms of potassium deficiency have never been observed on peach trees grown in this orchard. Differential fertilizer treatments were begun in the spring of 1943, and consisted of applications of 0.5, 1, 2, 3, and 5 pounds of K (as commercial KCl) per tree. Nitrogen and phosphorus were applied uniformly to the entire block. The block was laid out in randomized, single-tree plots.

Sampling and Analytical Procedures:—In collecting samples of leaves and woody tissue, the entire terminal growth was removed. Usually 10 terminal shoots were cut from each tree. Thus samples taken during the growing season were composed only of wood and leaves developed during that season, while samples of wood taken during the dormant period were produced during the immediately previous growing season. Samples were taken at equally distributed points around the circumference of each tree. In the Benner orchard where the treatments were applied to 9-tree plots only the center tree of each plot was sampled.

The samples of terminal growth were taken to the laboratory as soon as possible after cutting, and were divided into four equal parts transversely. The first section consisted of the youngest leaves and wood, and the second, third, and fourth sections progressively older growth, the last mentioned being the "basal" or oldest growth. The

sections naturally varied in length, according to the time of sampling, but were usually at least 10 centimeters long. After cutting into sections, the leaves (minus petioles) were removed from the woody portions, and the wood and leaf samples were dried in a steam-heated drying oven at a temperature of approximately 80 degrees C. When thoroughly dry, these samples were weighed, ground, and analyzed for potassium by the cobaltinitrite method of Wilcox (7).

Samples of fruit were collected from the trees in the college orchard at harvest time. The flesh was separated from the pits and both were dried. One sample of leaf petiole was taken, following the same procedure as outlined for leaves in the previous paragraph. All of these samples were analyzed for potassium by the cobaltinitrite method.

Experimental Results

Woody Tissue:—Samples of 1- and 2-year wood were taken on April 13, 1943, from trees in the Anderson orchard. In preparing these samples, the secondary growth (side branches) on the 1-year wood was analyzed separately. The results of the chemical analyses are given in Fig. 1. From this figure it is apparent that there was a definite correlation between age of wood and potassium content; the youngest wood showing the highest percentage of this element. The potassium content of the 2-year wood (Fig. 1B) was much lower than the 1-year wood (A), and showed little vari-

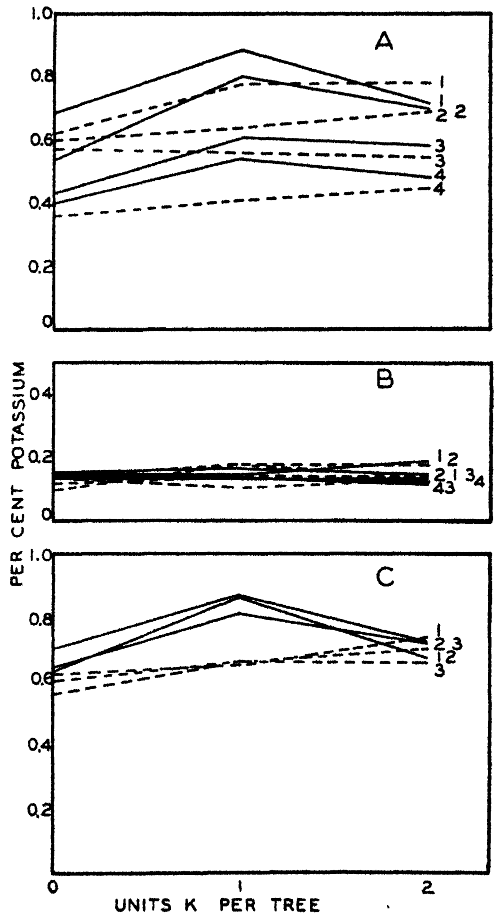


Fig. 1. Potassium content of wood—Anderson orchard, April 13, 1943. A represents the samples of one-year wood, divided into quarters; lines numbered 1 being the youngest (tip) wood, lines 4 the oldest (basal) portion. B represents the results on two-year wood, and C the results on secondary one-year wood (side branches), designated in the same way. The solid lines are samples taken from the Hale variety, dotted lines Hale Haven.

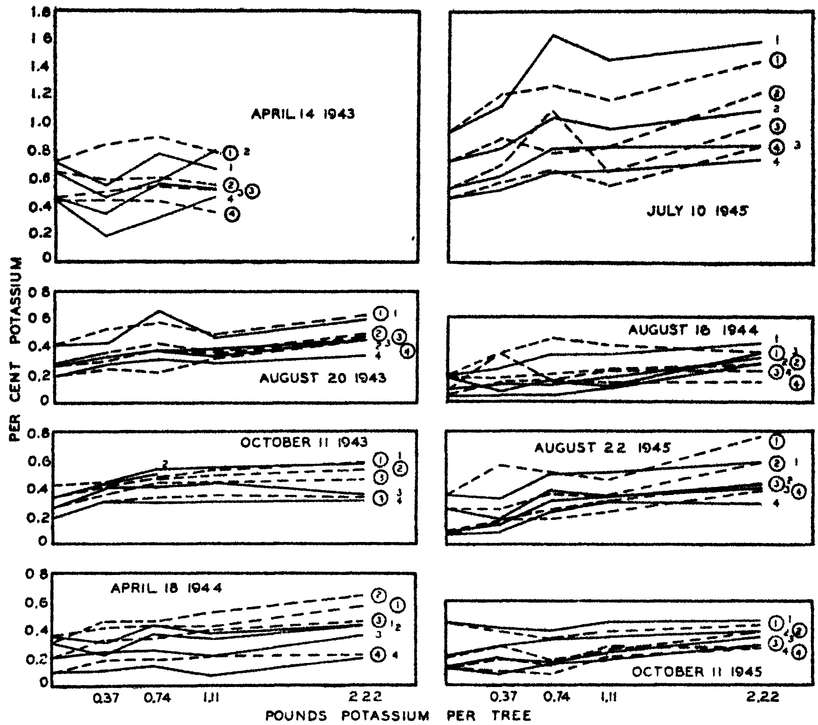


FIG. 2. Potassium content of one-year wood — Benner orchard, 1943–1945. Solid lines represent trees fertilized with KCL; dotted lines with numerals in circles, trees fertilizd with K_2SO_4. Numerals refer to age of wood as in Fig. 1.

ation. Likewise, there appeared to be little variation in the percentage of potassium in the samples of the secondary wood (C).

The potassium percentages in the Anderson wood samples did not show a high degree of correlation with potassium applications to the trees, although the trees receiving no potassium gave consistently low results. The data also indicated that variations in potassium content of 2-year and secondary wood appeared to be less consistent than in 1-year wood, and this latter tissue was used exclusively in the further studies.

In the Benner orchard, samples of 1-year wood were taken on the following dates: (1943) April 14, August 20, and October 11; (1944) April 18, and August 16; (1945) July 10, August 22, and October 11. The results of the analyses of these samples are given in Fig. 2. From this figure it may be seen that the variation in percentage of potassium between samples taken on any given date is relatively small except for the samples of July 10, 1945. In general, the trees receiving the largest amounts of potassium as fertilizer applications show the highest percentage of potassium in the wood, but the differences in

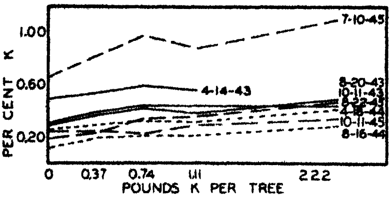


FIG. 3. Potassium content of one-year wood—Benner orchard. Averages of all analyses according to date and potassium application.

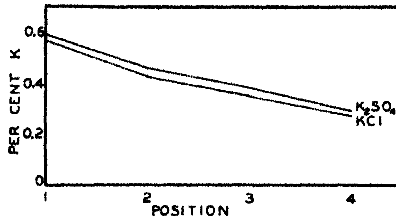


FIG. 4. Potassium content of one-year wood—Benner orchard. Averages of all analyses according to age of wood, position 1 being the tip, and position 4 the basal portion of the terminal growth.

composition between treatments are minor. This is shown in Fig. 3, in which the average K content is plotted according to treatment and sampling date. The negative correlation between age of wood and potassium content is consistent throughout the three years of the experiment. Fig. 4 gives the averages of analytical results plotted according to age of wood: position 1 being the youngest wood, position 4 the oldest, with 2 and 3 intermediate in age. This figure indicates the consistent relationship between age and potassium content of the wood. It also indicates that the trees fertilized with K_2SO_4 consistently contained slightly greater amounts of K than those fertilized with an equivalent amount of K as KCl. Each point in this figure represents the average of 39 analyses, so that the results may be considered to have rather high significance.

The effects of both age and K application are shown in Fig. 5. The lines in this figure represent averages of all wood samples taken in the Benner orchard, divided according to age of wood (lines 1, 2, 3, and 4), with the average potassium content of the wood plotted against the amount of potassium applied.

In the College orchard, samples of 1-year wood were taken on July 21, 1943, April 8, 1944, and July 12 and October 25, 1945. The results of the potassium analysis on these samples are given in Fig. 6. From this figure it is apparent that the potassium content of the two varieties (Elberta and Belle of Georgia) followed much the same pattern, and were similar in a general way to the results obtained in the Benner orchard. In nearly every case the trees receiving the largest amounts of potassium fertilizer applications showed the highest percentages of potassium in the wood. As in the case of the Benner trees,

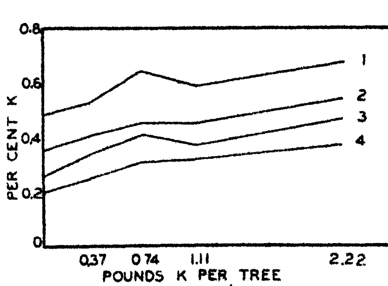


FIG. 5. Potassium content of one-year wood—Benner orchard. Averages of all analyses according to age of wood and potassium applications.

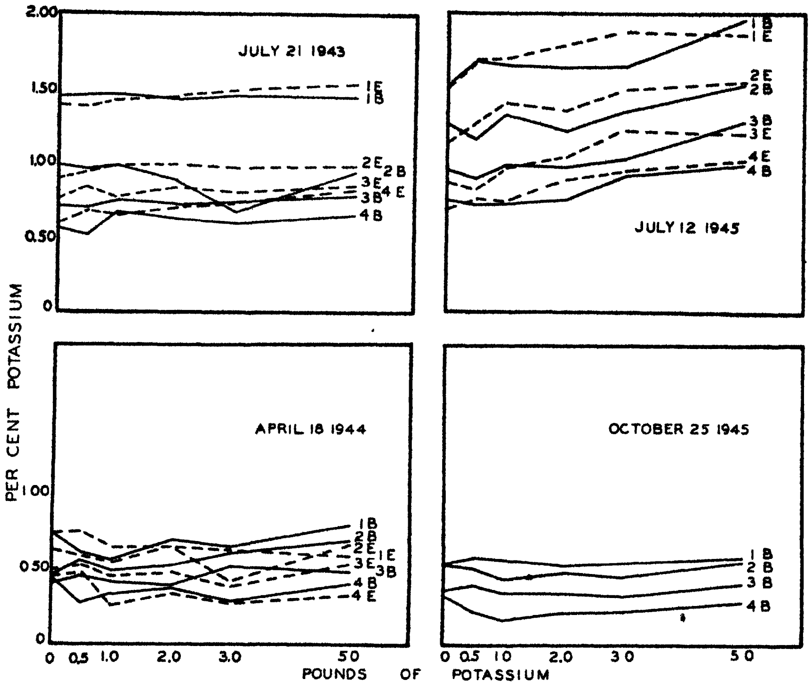


FIG. 6. Potassium content of one-year wood — College orchard, 1943–1945 Solid lines represent samples taken from Belle of Georgia variety, dotted lines from Elberta. Numerals indicate age of wood, as in previous figures.

however, these differences were small. This is shown in Fig. 7, in which the average K content is plotted according to treatment and sampling date (compare this with Fig. 3).

The correlation between the age of wood and potassium content is consistent: the youngest wood showing the highest potassium content. This is clearly shown in Fig. 8. In this figure it is evident that the slope of the curves is considerably steeper than were the corresponding curves for the Benner trees (compare Figure 4), and the potassium content higher.

Combining the data for all sampling periods, the mean values for the potassium content of the 1-year wood, plotted against potassium application, are given in Fig. 9. Comparing this figure with Fig. 5, it appears that in general, the amount of potassium in the 1-year wood did not vary so widely with potassium applications in the College orchard as in the Benner orchard. This may have been due to the higher general level of potassium in the wood grown in the former orchard, (more than twice as much), a possible indication that no serious potassium deficiency existed there.

Petiole Tissue:—Inasmuch as some workers have found that analyses of grape leaf petioles furnished an index of the nutrition of this plant, it was decided to analyze a series of leaf petioles from the peach. Only one sample of petiole tissue was taken for analysis; this was

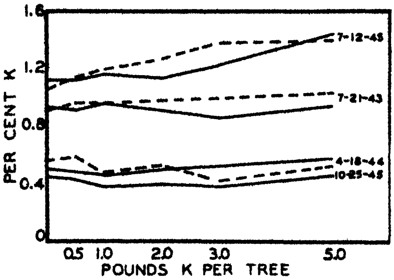


FIG. 7. Potassium content of one-year wood — College orchard. Averages of all analyses according to date and potassium application. Solid lines Belle of Georgia, dotted lines Elberta.

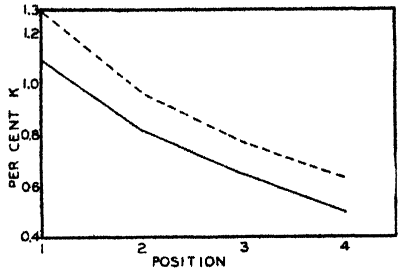


FIG. 8. Potassium content of one-year wood — College orchard. Averages of all analyses according to age of wood, position 1 being the tip, and position 4 the basal portion of the terminal growth. Solid line Belle of Georgia, dotted line Elberta.

from the Belle of Georgia variety grown in the College orchard, and was collected on October 25, 1945. The results of the potassium analysis are given in Fig. 10. While the potassium contents of these petioles varied over a wide range, and in general were correlated with the fertilizer applications, the results were not consistent enough to furnish a reliable index of potassium requirements.

Fruiting Tissue:—Two samples of mature peach fruits were collected on September 10, 1943, and September 6, 1944. The pits were

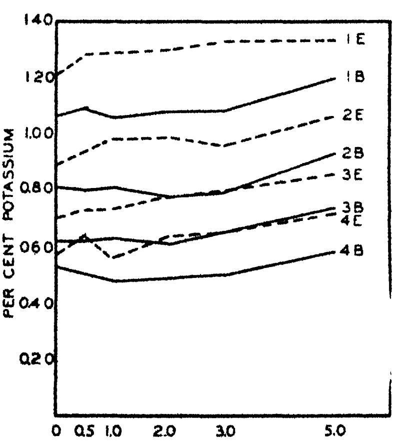


FIG. 9. Potassium content of one-year wood — College orchard. Averages of all analyses, plotted according to age of wood and potassium applications. Solid lines Belle of Georgia, dotted lines Elberta.

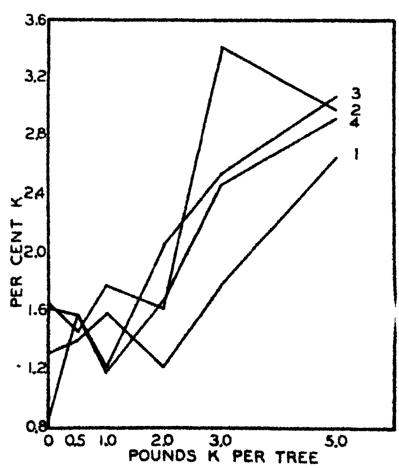


FIG. 10. Potassium content of leaf petioles — Belle of Georgia variety, College orchard, October 25, 1945, plotted according to age of one-year wood to which they were attached. (Numeral 1 indicates tip and 4 the basal portion of terminal growth).

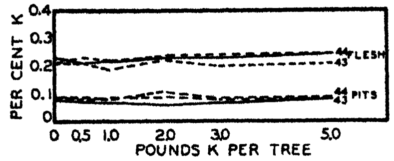


FIG. 11. Potassium content of flesh of fruits and pits — College orchard, 1943 and 1944. Solid lines Belle of Georgia, dotted lines Elberta.

separated from the fleshy portion of the fruit and analyzed separately. The results are given in Fig. 11. The analytical results in this figure are calculated on the fresh weight of the fruits, and are, therefore, considerably lower than the potassium figures reported throughout the other portions of this paper.

It is apparent from Fig. 11 that the variation in the potassium contents of the fruits and pits is very small, and would probably be of little use in determining the nutritional status of the trees in question. This is not surprising, since it is generally accepted that the fruiting bodies of the same variety of plants exhibit a rather uniform composition.

Leaf Tissue, Benner Orchard:—On July 17, 1942, samples of leaves from the entire 1-year growth were taken for analysis. The results are shown in Fig. 12 (A). The correlation between the potassium content of the leaves was better for the trees treated with KCl than for those fertilized with K_2SO_4, particularly at the higher levels of fertilization. In 1943, three sets of samples were taken, on June 30, August 20, and October 11. The results of these are shown in Fig. 12 (B, D and C). The June and August samples showed the most consistent results; the correlation between potassium in the leaves and in the fertilizer applications was excellent in these series. It is interesting to note that the youngest leaves had the lowest potassium content, with a regular increase in potassium percentage as the age increased, exactly the reverse of the potassium in the wood. The samples taken in October were more variable, and, although the general trend in leaf potassium was related to potassium applications, there were certain anomalous figures.

Fig. 13 gives the analytical data for the samples taken in 1944 and 1945. In the samples taken on August 16, 1944 (E), the correlation was good between leaf potassium and potassium application. Similar relationships are apparent in the samples taken on July 10, 1945 (F); August 22, 1945 (G); and October 11, 1945 (H), although in each of these cases there were certain figures which did not fall into the pattern exactly. This may have been due to the relatively small size of the sample. However, in every case, the samples receiving the highest amount of potassium in the fertilizer showed the highest leaf potassium, while most of the intermediate treatments fell into line rather well. The mean values for all of the Benner samples are shown in Fig. 14.

Leaf Tissue, College Orchard:—Three series of samples of leaves were collected from the trees grown in the College orchard, on July 21, 1943, July 21, 1945 and October 25, 1945. The results of the analyses are given in Fig. 15. Although more erratic than the results of the Benner experiment, Fig. 15 shows much the same trends. In practi-

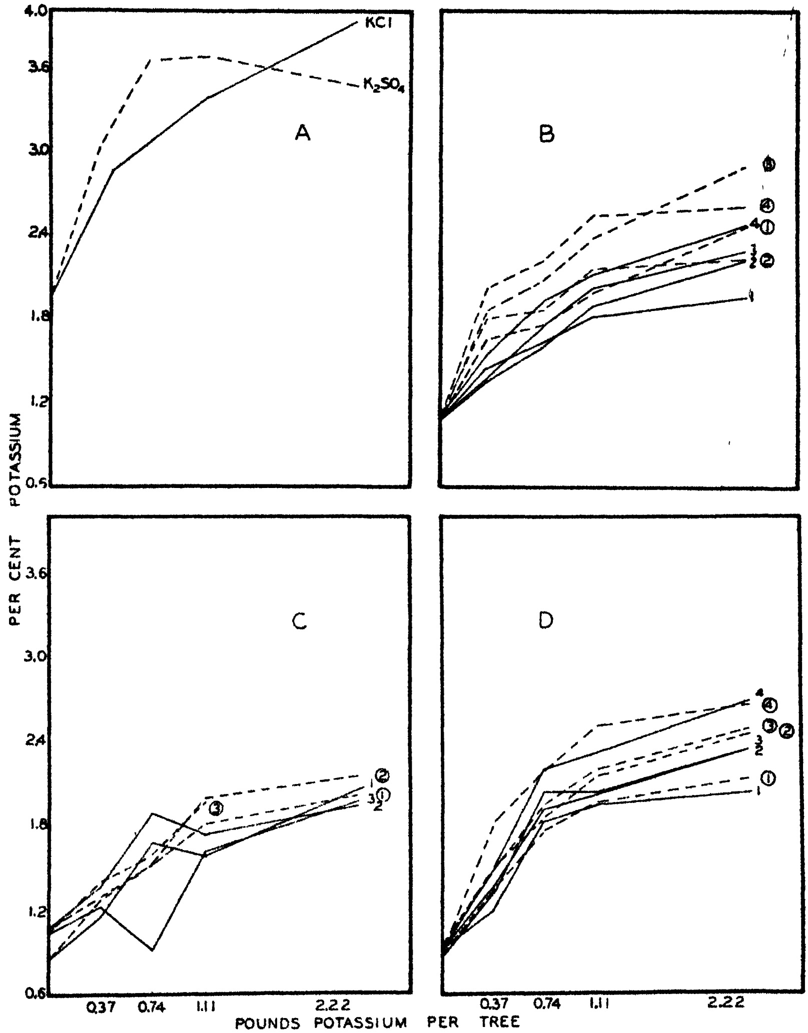


FIG. 12. Potassium content of leaves — Benner orchard. A indicates samples taken on July 17, 1942; B, June 30, 1943; C, October 11, 1943; D, August 20, 1943. Solid lines represent trees fertilized with KCl; dotted lines with numerals in circles, trees fertilized with K_2SO_4. Numerals refer to age of leaves, as in previous figures.

cally every case the potassium content of the leaves increased with age, and in general the more potassium applied to the trees, the higher the percentage in the leaves. There seemed to be no significant difference between the potassium content of the leaves of the two varieties. It is possible that the variations in the leaf potassium reflect the fact that there was no apparent potassium deficiency in this orchard; in other words, there may have been sufficient potassium in the soil on

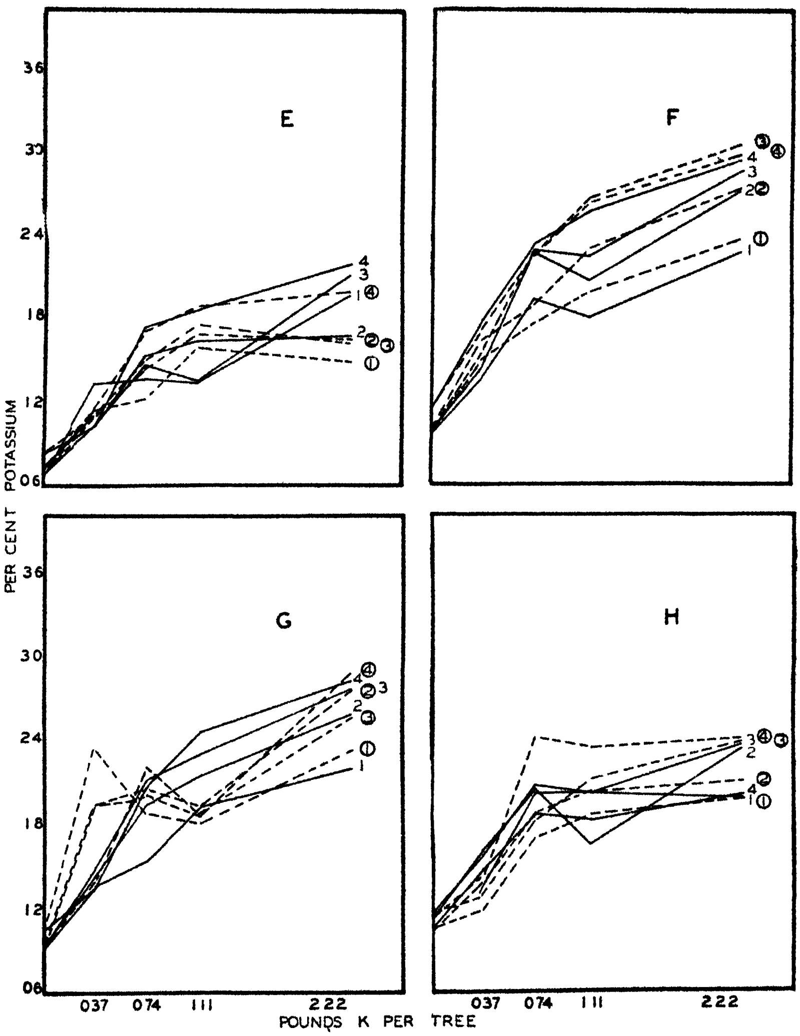


FIG. 13. Continuation of data presented in Fig. 12. Samples taken on August 16, 1944 (E) ; July 10, 1945 (F) ; August 22, 1945 (G) ; and October 11, 1945 (H).

which the untreated trees were growing to supply all of their requirements. This supposition is borne out by the relative levels of leaf potassium, which were much higher in the College orchard trees than in those from the Benner location.

The mean values for all leaf samples taken in the College orchard are given in Fig. 16.

The mean values for all leaf potassium determinations for both the Benner and College orchards are given in Fig. 17. In this figure the

potassium percentages are plotted against position of leaf on the terminal growth (age). It is obvious that the fertilizer applications (indicated in pounds of potassium per tree at the right of the figure) were reflected in the analyses of the leaves. This relationship was more marked in the trees in the Benner orchard, where, as has been indicated, the levels of leaf potassium were lower than in the College orchard. On the other hand, the effect of leaf position on leaf potassium was considerably more pronounced in the trees in the College orchard.

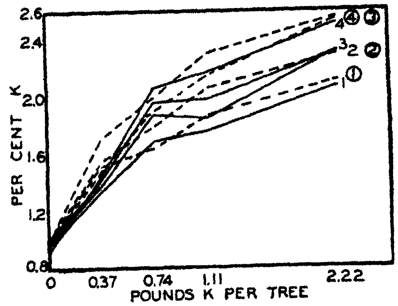
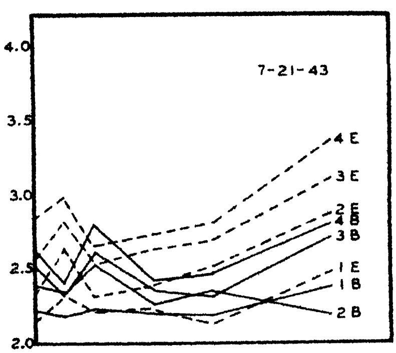
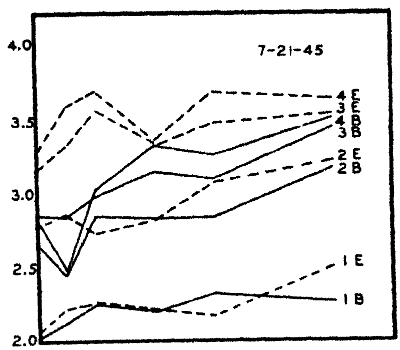


FIG. 14. Potassium content of leaves—Benner orchard. Averages of all analyses plotted according to age of leaves and potassium applications. Solid lines KCl trees; dotted lines (numerals in circles), K_2SO_4 trees.





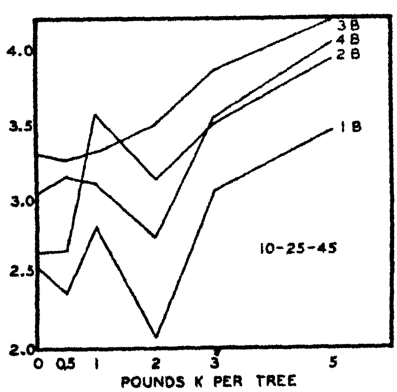


FIG. 15. Potassium content of leaves — College orchard, 1943–1945. Solid lines represent Belle of Georgia variety; dotted lines, Elberta. Numerals refer to age of leaves, as in previous figures.

DISCUSSION

On the basis of the data presented, the analysis of the petioles and fruits do not appear to furnish a reliable index of the potassium supply to peach trees. The potassium content of the 1-year woody tissue, however, correlated well with the potassium applications, and might serve as a relative index of potassium supply. In this connection it is interesting to note that there was a definite correlation between the age of the wood and potassium content, the youngest wood having the highest

potassium content, while the older the wood, the less potassium it contained. Samples of 2-year wood showed relatively low potassium content.

Although there was a consistent correlation between potassium applied in the 1-year wood, it is not considered that the analysis of the wood would be entirely satisfactory as a means of determining potassium supply, since a relatively large increase in potassium application produced a comparatively small change in the potassium content of the wood. Stated in another way, the potassium content of the 1-year wood does not appear to be sensitive to small changes in potassium supply. In fact, as is shown in Fig. 9, there is a far greater variation in potassium content due to position (age) of the 1-year wood than is attributable to potassium fertilization.

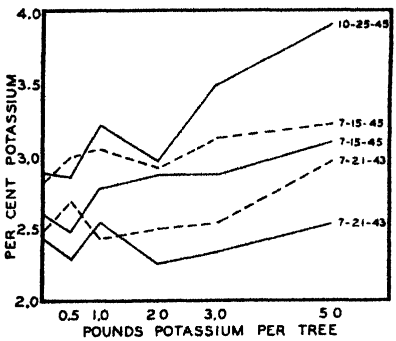


FIG. 16. Potassium content of leaves—College orchard. Averages of all analyses according to date and potassium application. Solid lines represent Belle of Georgia, dotted lines Elberta.

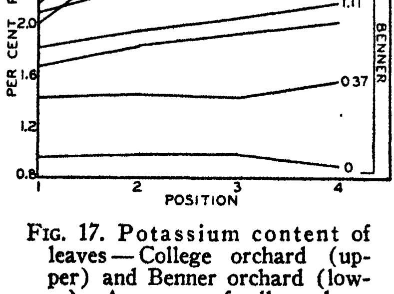


FIG. 17. Potassium content of leaves — College orchard (upper) and Benner orchard (lower). Averages of all analyses according to age of leaves, position 1 being the tip leaves, and position 4 leaves from the basal portion of the terminal wood. Pounds of potassium applied per tree in fertilizer are indicated at right.

The potassium content of the leaves growing on this season's wood appears to show the highest degree of correlation with potassium applications of all the tissues tested. Particularly when the soil on which the trees are growing is relatively low in potassium, as was the case in the Benner orchard, there is a direct and consistent relationship between potassium applied as fertilizer and leaf potassium (see Figs. 12 and 13). This relationship is not a linear one, but shows a characteristic curve as indicated in Fig. 14. Although the data are not sufficient to draw sweeping conclusions, it appears from the information available that samples taken during July and August give the most consistent results, probably because of the active growth of the peach tree during this period.

Like the woody tissue, the leaves on the terminal growth show a consistent difference in potassium content which is re-

lated to age. In the leaves, however, it was found that the youngest leaves contained the least potassium, thus reversing the trend observed in the 1-year wood. It is interesting to speculate on the possible movement of potassium in the tissues of the peach tree, but the figures available do no more than indicate the possibility of potassium migration from wood to leaves as these tissues become more mature. However, since the greatest numerical differences in leaf potassium content associated with potassium applications was found in the oldest leaves on the terminal growth, it would appear that these basal leaves would give the most reliable index of potassium supply.

To illustrate this point, let us consider Fig. 12 (B). In this figure, the leaves taken from the tip of the terminal wood varied between 1.31 and 1.96 per cent potassium, corresponding to an increase in potassium application of from 0 to 2.22 pounds of potassium per tree, respectively. In the leaves from the basal portion of the current wood, however, the percentage of potassium varied between 1.09 and 2.60, with the same application differential. In the tip leaves, then, the application of 2.22 pounds of potassium caused an increase of 0.65 per cent in the potassium content, while in the basal leaves, the same application caused an increase of 1.51 per cent. Similar differences in favor of the basal leaves can be found in most of the data given in Figs. 12, 13, 15, and 17. It is, therefore, suggested that for the most sensitive index of potassium fertilization in the peach tree, leaves for chemical analyses be selected from the basal (oldest) portion of the terminal wood.

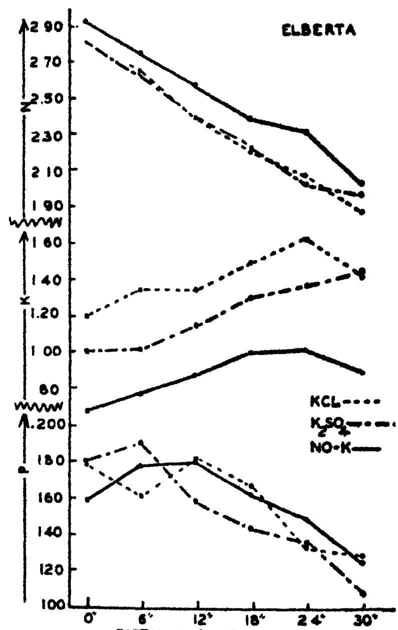


FIG. 18. Nitrogen, phosphorus and potassium percentages in peach leaves — Benner orchard, 1939. Data plotted against age of leaves (distance from tip on terminal growth). Data from Tomkins.

The relative levels of leaf potassium in this experiment agree with the findings of other investigators. In the Benner orchard, where some of the trees receiving no potassium showed characteristic symptoms of deficiency of this element during their first 2 years of growth, the leaves from these untreated trees contained approximately 1 per cent potassium or less. This figure has been given by Cullinan *et al* (3) as characteristic of incipient potassium deficiency. No symptoms of potassium deficiency have been observed on peach trees growing in the College orchard, and trees in this orchard receiving no potassium never showed leaf potassium percentages less than 2.0.

Working in the Benner orchard, Tomkins (8) found that while the potassium content of the leaves increased with age, the nitrogen and phosphorus percentages showed a consistent and regular decrease with age. Fig. 18, taken from Tomkins' work, illustrates this point. For this reason, the reader is reminded that the conclusions of this present study apply only to the element potassium; correlation studies with other elements may lead to quite different conclusions.

Summary

Chemical analyses of wood, petioles, fruits and leaves from peach trees fertilized with a wide range of potassium applications indicated that of these tissues the leaves taken from the terminal growth furnished the highest degree of correlation between leaf potassium and potassium application. It was further found that leaves taken from the basal (oldest) portion of this season's wood were most suitable for estimating the level of potassium supply available to the trees.

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Factors Affecting Branching and Growth of Newly Transplanted Tung Trees Trained to Vase Form

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A MAJOR criticism of the practice of training tung trees to the "direct vase"[1] form has been the inability to produce consistently trees having a satisfactory number of primary branches. Too many trees develop with only two or three primary branches, which diverge at sharp angles; and such trees are apt to suffer breakage. Breakage due to poor initial structure is undoubtedly minimized under conditions of moderate growth and yield. The present tendency to use improved cultural and fertilizer practices often results in increased growth and early and heavy bearing, which may bring about extensive breakage if the structure of the tree is not adequate. In order to evaluate properly the direct vase type of training it is necessary to determine its possible limitations and to devise methods of insuring, if possible, the formation of an adequate number of primary branches on each tree.

MATERIALS AND METHODS

Budded trees of the clone F–555[2] and seedlings from open-pollinated seed of a tree designated F–578 were chosen for the experiment. Trees of F–555 are naturally high-headed and are among those most easily trained to vase form. Trees of F–578 are naturally low-headed and tend to produce few primary branches as a result of heading back. The trees of F–555 were budded in August 1945 on several different rootstocks. Seed of F–578 was sown in the nursery in the spring of 1945 and of 1946 to produce the 1- and 2-year-old seedling trees used in the experiment.

In 1947 these trees were planted in the orchard in two different setups designed to evaluate the factors contributing to success in forming a desirable vase form tree, namely, (a) age of nursery trees planted; (b) initial tree size at time of planting; (c) variation in pruning methods; (d) residual effect of fertilizer used in the nursery; and (e) rootstocks.

In the setup with F–578 seedlings a split plot design (1) was used in which the main plots consisted of the four factorial combinations of two sizes of trees with two dates of pruning. The average diameters of the large and small trees at planting time were respectively 2.66 and 2.07 contimeters. When taken from the nursery all trees were cut back to 30 inches in height. The pruning, which in one case was done February 27 at planting time and in the other case on April 10 after

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[1]The term "direct vase" is applied to the vase form where the tree is cut off at the desired height at the time of transplanting or shortly thereafter, as opposed to the term "delayed vase" where cutting back is done at the beginning of the second year.

[2]Tung tree selections are designated by a serial number combined with an initial representing the State in which the original tree was found, A for Alabama, F for Florida, G for Georgia.

the buds had begun to swell, consisted simply in heading back to 18 inches. The main-plot treatments were replicated six times.

Each main plot consisted of six trees and was divided into three subplots of two trees each, according to age and fertilizer treatment in the nursery, namely, (a) 1-year-old nursery trees that had been fertilized with a commercial 4–8–6 mixture at about 600 pounds per acre; (b) 2-year-old nursery trees that had received the same fertilizer as above the first season, but none the second season; (c) 2-year-old nursery trees fertilized as above the first season and fertilized with about 200 pounds per acre of an 11–8–6 mixture the second season.

In the setup with trees of the clone F–555 the main plots consisted of the six factorial combinations of two dates of pruning and three rootstocks; these treatments were replicated four times. The three rootstocks were open-pollinated seedlings of three parent trees, A–36, F–551, and G–52. The pruning treatments were the same as those used with the F–578 seedlings.

Each main-plot consisted of eight trees and was divided into four subplots of two trees each according to four treatments representing the factorial combinations of two fertilizer treatments in the nursery with two grades of trees according to size at planting. The fertilizer treatments, which were used in 1946, the year the buds were forced, comprised (a) check, no fertilizer, and (b) 200 pounds per acre of an 11–8–6 mixture. The average diameters of the large and small sizes of the fertilized trees were 2.37 and 2.18 centimeters, respectively; and for the unfertilized trees they were 1.95 and 1.86 centimeters, respectively.

Observations made soon after planting indicated that the age of trees planted, tree size at time of planting, pruning methods, and fertilizer applications in the nursery, had a definite influence on the character of vase form trees developed. Hence records were taken on: (a) number of primary branches formed on the 18-inch trunks; (b) number of primary branches forming an angle of 50 degrees or greater with the trunk; (c) number of trees with five or more primary branches over 5 inches long; and (d) total linear growth at specific dates during the growing season.

Owing to press of other work it was not possible to record the diameter of the trees at planting time. The initial diameter was determined later in the season from measurements of the xylem cylinder exposed at the top of the 18-inch trunks.

The trees were cultivated six times during the growing season. They were each given ½ pound of 4–8–6 fertilizer early in May, and 1½ pounds in June. One-quarter pound of zinc sulphate was also applied to each tree in May.

Total linear growth of all F–578 seedling trees was measured on April 21, May 6, May 22, June 2, June 17, August 6, August 22, and September 8. Periodic linear growth measurements of budded F–555 trees were not taken.

The experimental design and statistical analyses used make it possible to consider main effects and interactions of the various factors under consideration.

Results

Two-year-old F–578 seedling trees fertilized the second year in the nursery proved by far the best (Table I). On the average they formed 9.69 primary branches per tree, of which 4.60 were of acceptable[3] length and formed angles of 50 degrees or more with the trunk. The 1-year-old trees produced 3.77 primary branches of which 0.98 were of acceptable length. The percentages of trees having five or more acceptable branches were 89 and 2, respectively, for the fertilized 2-year-old and the 1-year-old trees. These differences all attained statistical significance at the .001 level. The 1-year-old trees started growth most rapidly, and the fertilized 2-year-old trees most slowly; but by the end of the season the 2-year-old trees were far ahead, having 1,285 and 1,185 centimeters linear growth, respectively, for the fertilized and unfertilized as opposed to 779 for 1-year-old trees. On the basis of linear growth per terminal, the 1-year-old seedlings grew at a significantly faster rate than the 2-year-old seedlings in the late summer. The 1-year-old seedlings made approximately 91 per cent of the total linear growth after June 17, while 2-year-old trees produced approximately 76 per cent of the total linear growth after June 17.

The differences in total growth observed on September 8, and also those on April 21 and June 17, (Table I) attained statistical significance at the .001 level. Corresponding differences were observed in (a) average number of days that the daily growth rate fell below that

TABLE I—The Effect of Initial Tree Size, Pruning, Tree Age, and Nursery Fertilizer Applications on Subsequent Growth of Newly Transplanted F–578 Seedling Tung Trees the First Year in the Field*

Treatment	Primary Branches Per Tree: Total No.	Primary Branches Per Tree: No. With Angle of 50 Degrees Or More With Trunk**	Trees With Five Or More Acceptable† Primary Branches (Per Cent)	Total Linear Growth Per Tree (Cms): Apr 21	Total Linear Growth Per Tree (Cms): Jun 17	Total Linear Growth Per Tree (Cms): Sep 8	No. Days of Retarded Growth‡	No. Growing Points Aug 22	Linear Growth Per Growing Point Aug 6 to 22 (Cms)
Small nursery trees	6.47	2.57	48	5.77	180 0	946.0	20.8	26.9	8.06
Large nursery trees	7.87	3.44	65	4.83	259.0	1220.0	18.5	35.6	6.72
Difference sig at..	0.01	0.01	0.05	—	0.001	0 001	—	.001	0.05
Pruned Feb 27	6.58	2 67	52	9.16	231.0	1091.0	24.2	30.9	6.84
Pruned Apr 10....	7.76	3.34	61	1.44	207.0	1075.0	15.1	31.7	7.94
Difference significant at........	0.01	0.05	—	0.01	0.05	—	0.01	—	—
1-year trees......	3.77	0.98	2	7.21	67.0	779.0	37.2	18.0	9.81
2-year trees fertilized 2nd year..	9.69	4.60	89	2.62	311.0	1285.0	8.7	40.8	6.10
2-year trees unfertilized 2nd year	8.07	3.44	79	6.08	279.0	1185.0	13.1	35.0	6.26
Difference significant at.....	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

*All data in this table are main effects (over-all averages) from a factorial experiment.
**With minimum length of 5 inches.
†Acceptable is defined as meaning 5 inches or more in length.
‡Growth rate lower than for period April 21 to May 8.

[3]Branches 5 inches or more in length are considered acceptable.

for the period April 21 to May 8; (b) number of growing points August 22; and (c) linear growth per growing point for the August 6 to 22 period.

The large nursery trees of all three types according to age and fertilization produced on the average 7.87 primary branches, whereas the small trees produced 6.47 branches; and 65 per cent of the large trees had five or more acceptable primary branches as opposed to 48 per cent for the small ones. These differences had statistical significance at the .01 and .05 levels, respectively. Outstanding differences, with statistical significance at the .001 level, occurred in total linear growth, which on September 8 was 1,220 and 946 centimeters, respectively, for the large and small trees. As an average for both sizes of nursery trees, those pruned late formed the better heads having on the average 7.76 primary branches per tree, as compared with 6.58 for the trees pruned at planting time; and of these, 3.34 and 2.67, respectively for the late and early pruned trees, were of acceptable length and formed angles of 50 degrees or more with the trunk. The differences in average numbers of total and of acceptable branches attained statistical significance at .01 and .05 respectively. Late pruning did not increase total linear growth (Table I).

In the experiment with budded trees of F-555, rootstocks had a significant effect (.05 level) on the number of primary branches formed (Table II). The average total linear growth per tree was 664, 860, and 1002 centimeters, respectively, for trees on the F-551, A-36, and G-52 rootstocks, the differences attaining statistical significance at the .01 level. Although trees fertilized in the nursery during the season in which the buds were forced were larger than those not fertilized, no significant differences were observed in branching or growth of the trees in the orchard (Table II).

TABLE II—THE EFFECT OF INITIAL TREE SIZE, PRUNING, NURSERY FERTILIZER APPLICATIONS, AND SEEDLING ROOTSTOCKS ON THE BRANCHING AND GROWTH OF NEWLY TRANSPLANTED BUDDED F-555 TUNG TREES*

Treatment	Primary Branches Per Tree		Trees With Five Or More Acceptable† Primary Branches (Per Cent)	Total Linear Growth Per Tree to Aug 8 (Cms)
	Total No.	No With Angle of 50 Degrees or More With Trunk**		
F-551 rootstock	5.84	2.51	75	664
A-36 rootstock	5.92	2.41	76	860
G-52 rootstock	5.36	1.94	64	1002
Difference significant at	0.05	0.05	——	0.01
Pruned Feb 27	5.07	1.58	53	906
Pruned Apr 10	6.34	2.99	90	777
Difference significant at	0.001	0.001	0.001	——
Small nursery trees	5.32	1.95	62	802
Large nursery trees	6.09	2.62	81	882
Difference significant at	0.001	0.001	0.001	——
Fertilized second year	5.84	2.33	70	800
Unfertilized second year	5.57	2.24	82	884
Difference significant at	——	——	——	——

*All data in this table are main effects (over-all averages) from a factorial experiment.
**With minimum length of 5 inches.
†Acceptable is defined as meaning 5 inches or more in length.

The larger size of trees from both fertilized and unfertilized lots formed the better heads, having an average of 6.09 primary branches per tree, of which 2.62 were of acceptable length and formed angles of 50 degrees or more with the trunk; the corresponding data for the smaller trees were 5.32 and 1.95. Eighty-one per cent of the larger trees had a minimum of five acceptable branches as compared with 62 per cent for the smaller trees. All these differences attained statistical significance at the .001 level (Table II).

Late pruning also increased the total number of branches per tree, the percentage of trees with five or more acceptable branches, and the average number of acceptable branches forming angles of 50 degrees or more with the trunk (Table II). Neither size of stock at planting nor date of pruning had any significant effect on the total growth made by the F–555 budded trees.

The advantage of late pruning over pruning at planting, as reported above, is supported by similar results in several preliminary experiments with budded F–555 trees conducted in southern Georgia and northwestern Florida in 1945 and 1946.

Discussion

For several years it has been observed that newly transplanted tung trees begin the growing season with a relatively high rate of growth. This high growth rate has been of short duration, followed by a decided decrease in growth rate often extending over a considerable number of days. It has been suggested that a depletion of initial reserves and adverse moisture relations have been factors causing this early spring decrease in growth rate (2).

A decline in the daily rate of growth during spring and early summer assumed importance in the present experiments with F–578 seedlings and was found to be closely correlated with the number of primary branches produced per tree. The correlation coefficient between the number of days during which the daily rate of growth was depressed and the number of primary branches produced for the trees in the 72 sub-plots, was −.759, where ±.380 is significant at the .001 level. The data from the same sub-plots showed a highly significant correlation of −.438 between the total linear growth produced by the trees by September 8th and the number of days that the slow daily rate of growth extended. Both the use of 2-year-old nursery trees for planting and the late pruning significantly decreased the duration of the period of slow growth rate and also significantly increased the number of primary branches produced per tree. Furthermore, the initiation of shoot growth in early spring (April 21) was also significantly delayed.

The great difference in size between the 1-year-old and 2-year-old seedlings and between the small-diameter and large-diameter trees suggests similar large differences in stored reserves. Depletion of reserves could theoretically explain the decrease in growth rate during early spring, although other factors must be considered. The senior author (2) has previously shown that the decrease in daily rate of growth occurred irrespective of cultural treatments. Following the

first sharp drop in growth rate the trees grown under conditions of clean cultivation gradually recovered, and after approximately 45 days the growth rate equaled or surpassed the initial high rate of growth. Trees grown under less favorable cultural conditions showed the same sharp initial decrease in growth rate, which was followed by a further and continual decline, and they reached the lowest rate of growth after approximately 45 days. The sudden decrease in growth rate may be due to depletion of reserves or to unfavorable environmental conditions, such as lack of optimum moisture. The subsequent growth rate is dependent on cultural conditions, which may conserve moisture and may augment the supply of elaborated food by accelerating the rate of photosynthesis.

Summary

In an experiment with seedling tung trees of a progeny known as F–578 and budded trees of the clone F–555, it was found that better vase form heads were developed when the trees were cut back to a height of 18 inches in April, after the buds began to swell, rather than at planting time in February. Such late pruning had no significant effect on total linear shoot growth.

One-year-old seedling trees formed far fewer primary branches than 2-year-old trees. Two-year-old seedling trees fertilized both seasons in the nursery formed more primary branches than similar stock fertilized only the first season. Corresponding differences in total linear shoot growth per tree occurred.

Although highly significant differences in total linear growth of budded trees of the clone F–555 were attributable to rootstock, there was comparatively little effect of rootstock on the number of branches.

With all ages and types of nursery trees the large trees produced more primary branches and made better linear shoot growth than did the small trees.

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Recent Research in Breeding and Selection of Tung[1]

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The tung tree belongs to the Spurge family, Euphorbiaceae, and the genus, *Aleurites*. There are five species; namely, *Fordii, montana, moluccana, cordata*, and *trisperma* (4). This paper will deal only with *Fordii* and *montana*, the two most important as sources of drying oil. Because of its hardiness with respect to cold and adaptability to the Gulf region of the southeastern United States, *Fordii* is the only species grown commercially in the United States. *Aleurites montana* is very susceptible to frost injury and is the most important species in South China and other tropical countries. In the continental United States only central and southern Florida would be climatically suited for growing *Aleurites montana*.

Breeding work with *Aleurites montana* has been conducted in Indo-China, in the Dutch East Indies, and in Nyasaland, South Africa. Reports of the work in Indo-China and in Batavia were not available to the writer.

Webster (17) found that *Aleurites montana* is better adapted to Nyasaland than *Aleurites Fordii*. He has ceased to select and breed *Aleurites Fordii*, and since 1936 has worked exclusively with *Aleurites montana*. He states that, "Some 40 to 50 per cent of the trees of *Aleurites montana* are very predominately male, while the remainder, known as "bearers", produce a much higher proportion of pistillate flowers, and consequently set much more fruit". In a plantation where 75 co-called "bearing" trees produced an average yield of 30.4 pounds of air dry seed, the best 12 trees produced an average yield of 50.8 pounds. Four of the top ranking trees were propagated by open pollinated seed and by budding. The seedlings up to 5 years of age were little if any better than those from unselected "bulk" seed, but the trees budded on *Aleurites montana* rootstocks yielded about twice as much as the seedlings (17). Webster reported that on good soil and under good culture, some of his selected parent trees produced average yields of 17.0 pounds of air dry seed per tree at 4 years of age, 20.2 pounds at 5 years, 25.3 pounds at 6 years, 31.3 at 7 years, and 40.5 at 8 years (18). Since 1 pound of air dry seed is equivalent to approximately 2 pounds of whole fruit, these yields compare very favorably with the production of the best individual trees of *Aleurites Fordii* in this country.

Aleurites Fordii is native to China but since the fruit is not edible, the Chinese have paid little attention to its improvement. Ma and Li of the National Chiang Kai-Shek University, Kiangsi, China, have

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attempted to classify tung into 11 varieties, according to shape of fruit, form of tree, color of the flowers, oil content of fruit, and regularity of bearing. However, these can not be considered as true taxonomical varieties. Yuh, Chia and Hoh of the Chinese Tung Oil Research Institute, China, revised Ma and Li's classification, condensing the list into four varieties. Ying-Chen Li (11), in his comparative study of the varieties of the Chinese tung, based on quantity, quality and oil producing ability, has grouped the various types of trees into the following varieties:

1. *Aleurites Fordii* (the type species so-called large rice tung)
2. Small rice tung
3. Deep-color-flower tung
4. Light-color-flower tung
5. Persimon-cake tung
6. Peach or fire-wood tung
7. Annual fruiting tung

These classifications of tung have been of little value. Progress in tung breeding seems to be made, not by grouping seedling trees together, but by intensive study of the characteristics of individual trees, the best of which are used as breeding stock.

Thus, when tung was introduced into the United States by the United States Department of Agriculture, the 200 pounds of seed from Consul General Wilcox of Hankow, China, was of unknown parentage. Some seedlings from this lot were sent to Tallahassee, Florida, in 1906, and were planted by William H. Raynes. However, it was not until 1923 that any appreciable acreage was planted. By this time the Florida Agricultural Experiment Station at Gainesville began intensive tree propagation (12). B. F. Williamson practiced selection from 1920 to 1930. He believed that seedlings show characteristics of the parent tree to a remarkable degree. He asserted that 95 per cent of seedlings come true to the parent type, and that these characteristics of the original tree were transmitted down to the fourth generation. He suggested that the reason for the potency he observed was that trees have been propagated for thousands of years from seed (19). However, as might be expected from experience with other fruit or nut trees, and as Mowry has reported, wide variations of size of fruit, percentage of hull, seed, kernel and oil are found among seedling tung trees. Mowry further states that, "The widely differing fruit characteristics of different seedlings are inherent and are due only in small part to environmental influence" (13). Angelo (1) has pointed out that, "There is a wide variation in tung seedlings, in type or shape of tree, vigor, cold resistance, time of ripening, and other fruit characteristics, number of fruit in a cluster, and regularity of bearing".

Dickey (6) studied five characteristics of seedling progenies of two parent trees, as follows: (a) habit of growth; (b) type of inflorescence; (c) shape and size of fruit; (d) time of fruit fall; and (e) size of crop. He found 56.9 per cent of the progeny from open pollinated seed of the tree designated Florida 2, resembled the parent in

all five characteristics. The corresponding percentage for Florida 9 was 59.4. The percentages of seedlings that failed to resemble the parent in any one of the five characteristics were 3.1 and 4.9, respectively, for the F–2 and F–9. This rather exact study denotes considerable variation among tung seedlings from a single parent tree.

In 1938 the State of Mississippi made available funds for the establishment of an Experimental Tung Field which is located 10 miles east of Poplarville, Mississippi, on the Poplarville-Bogalusa, Louisiana, hiway. The research program at the Experimental Tung Field is a cooperative one between the United States Department of Agriculture and the Mississippi Experiment Station. Likewise, funds appropriated to the United States Department of Agriculture for research on tung made possible a large scale selection and breeding program that extended from Florida across the tung belt into Texas. Practically all orchards of mature bearing trees were visited and the observers scouted the orchards by advancing from tree to tree, each man taking one or two rows at a time. A primary consideration in making these selections was high yield. In this connection the question of fruiting habit as distinguished by "single" and "cluster" types is frequently raised. Although the number of fruit per cluster is influenced considerably by environment and season, some trees inherently tend to have a higher average number of fruits per cluster than others. However, yield is not necessarily correlated with number of fruits per cluster. Dickey and Reuther (7) point out that, "no tree should be discarded as potential breeding stock simply because it bears a single fruit per terminal". In fact they found the highest yielding tree out of 10 studied, was of the single type. Although it is believed that in general trees with cluster type bearing habit will outyield those that tend toward the single type, in the work of the United States Department of Agriculture, total yield was the only consideration; no effort was made to avoid or to select the cluster type.

Regularity of bearing was also considered important. Production in previous seasons can be estimated from the seedstems, which persist on the tree. Trees that make good shoot growth, while bearing a good crop, are most likely to differentiate pistillate flowers for the succeeding season.

The characteristics of the fruit were carefully studied. Large fruits are advantageous to harvest. Fruits with thin hulls and well filled nuts are most likely to have good oil content. Other things being equal, fruits that mature early are preferred to those that mature late. Subsequent studies indicated that the oil content of fruit that matured early was equal, if not superior to that of late maturing fruit. Early ripening fruit from 25 trees had an average oil content of 22.2 per cent, fruit ripening in midseason from 22 trees had an average oil content of 19.7 per cent, and the late ripening fruit of 7 trees averaged 20.1 per cent oil.

Tree characteristics such as strong, well spaced branches and strong leader were considered, although of secondary importance. Supreme weight was ascribed to cold resistance and the ability to bear fruit in years when most of the crop was destroyed by frost. Immunity

to frost may arise either from late blossoming or from a physiological ability to withstand low temperature.

In February 1939, the tung orchards of the southern United States experienced a severe freeze which reduced the crop to about 10 per cent of normal. This afforded an excellent opportunity to select trees for cold resistance, and more than 200 such selections were made that year. Only trees that had borne heavy crops in 1936 and in 1938 and a fair crop in 1937, when a late damaging spring frost occurred, were selected (1). It is a well known fact that the seedlings of *Aleurites Fordii* do vary in cold resistance. Fernholz and Potter (8) show in their experiments on the resistance of the tung tree to low temperatures, that there is a highly significant difference in resistance to cold of progenies of selected trees. Fernholz and Potter (9) further state that in their survey of injury to tung trees by low temperatures occurring in November 1940, they found little difference in the amount of injury to budded trees as compared to seedlings, but the relative hardiness of either a clone or a progeny depends largely on its parentage. For example, in a budded block of trees, only 10 out of a total of 746 trees of the clone M–1 were injured, while 553 out of 666 trees of the clone M–2 were either killed or seriously injured in the freeze of 1940.

In all 604 selections were made in 1938 and 1939, and some additional ones have been made in subsequent years. Open pollinated seeds were taken from every tree and buds were taken from about 125 of the most promising ones for the propagation of clones. Twenty-five to 100 of the seedlings from each tree were planted in test orchards at Bush and Folsom, Louisiana. There is an aggregate of more than 1,000 acres in these trial orchards, in which each tree can be traced back to the pistillate parent from which the seed was taken. As these trees came into bearing, very striking differences were observed in the degree of uniformity among seedlings of individual trees. Some very promising parent trees, as for example the Lamont (F–542), produced an exceedingly heterogeneous lot of seedlings. Others, for example the A–36, produced seedlings fully equal in any clone in uniformity of tree type, bearing habit and productivity (15). Lagasse *et al* (10) have recently shown that the same is true with respect to fruit characteristics such as size, percentage oil in kernel, and percentage kernel in the whole fruit. It is clearly evident that the merits of the tung tree as a seed parent are most advantageously judged by the performance of its seedlings in the orchard.

In the fall of 1942 yields of 18 progenies were taken, three of which were exceptionally productive. Seedlings of the selection Gahl (L–51) produced on the average of 9.43 pounds per tree. The 50 trees in this progeny were very uniform in size and appearance. The next highest yielding progeny was L–46, with an average of 5.93 pounds per tree. The third highest yielding seedlings were from the selection A–16a, with an average of 4.63 pounds per tree. It was noted in this study that many of the progenies so closely resembled the female parent in tree shape and in size and shape of fruit that the parent could be named from the appearance of its seedlings (2). The observations and yield

records subsequently obtained have served to confirm and to emphasize the above results. Among the parent trees which have finally proved to be some good sources for seed are: L–46, L–47, LaCrosse (F–99), and M–42. Two other progenies that throw about 25 per cent off-type seedlings are Isabel (L–2) and Gahl (L–51). The Gahl has also proven to be the most cold resistant progeny known (14). The L–47 progeny was among the top seedlings in yields and is one of the most uniform in tree type (16).

Another good seedling progeny that should be mentioned is the McKee, the merits of which were first noted in 1937 by Gaston Lanaux, a private tung grower of Folsom, Louisiana. An orchard composed of third and fourth generation seedlings from the original McKee tree, now growing near Folsom, Louisiana, is exceptionally uniform in all respects (15).

It is clear that only the exceptional tung tree produces uniformly satisfactory seedlings. Potter (15) has suggested that, "These exceptional trees must either produce seed parthenocarpically or else they must be rather homozygous for a number of genes, possibly dominant genes, that determine tree type, and the important characteristics of the fruit. If cross-pollination takes place to any great extent in tung orchards, it is necessary to assume that the genes concerned are largely dominant. In the event that these trees are truly parthenocarpic, they will continue to come true to seed indefinitely. However, if the uniformity of the seedling progeny depends on the genotypic constitution of the parent tree, a certain amount of segregation and recombination of genes will take place, hybridization with other trees will occur, and the seed from second and later generations of trees will be inferior to that of the original parent. Until critical evidence is available, it seems wise for those who wish to grow seedling tung trees to use first generation seed insofar as possible." Seed from the original tree, or from trees budded from the original tree is considered to be first generation seed.

Relatively few budded trees have been produced in this breeding program, but those have been tested in experimental designs that afford rather precise evaluation of their merits. In plantings distributed from Silsbee, Texas, to Gainesville, Florida, five clones have produced rather consistently and in such an outstanding manner that it was believed they should be made available to all growers who wished to propagate them. At the Experimental Tung Farm in Pearl River County, Mississippi, trees of the LaCrosse (F–99) clone produced 4 pounds of air dry fruit per tree when 3 years of age and 19 pounds at 4 years of age. In 1947, when 7 years of age, these trees had an average yield of 75 pounds of air dry fruit, equivalent to a yield of more than 2 tons per acre of 60 trees. Therefore, on November 25, 1947, the United States Department of Agriculture named and released the following varieties of tung: Isabel (L–2), Gahl (L–51), Cooter (F–4), LaCrosse (F–99) and Lamont (F–542). The names signify the town or location in which the original tree was found. The five varieties have been described in detail by Crane *et al* (5). One other variety of budded tung tree, the "Fairchild", developed co-

operatively with the Georgia Agricultural Experiment Station, had previously been patented and introduced by the Wright Nursery Company of Cairo, Georgia.

In addition to developing seedling progenies and clones from the orginal *Fordii* selections, the United States Department of Agriculture began a program of hybridization in 1940. Crosses have been made between individual selected parents with a view of combining their most desirable characteristics. Superior trees developed in this manner will probably need to be propagated vegetatively, since they will certainly be heterozygous and there is but little probability that they will produce apogamous seed. Some inbreeding in promising progenies and clones has been done and is being carried on now to isolate genotypes for later hybridization (14). This controlled pollination work is a slow process that will require years of fruition. Potter (14) states that second and third generation selfs are now in the orchards and also a number of 6-year-old hybrids, but to date no publication on this phase of the work has been issued.

Some crosses have been made between the species *Aleurites Fordii* and *Aleurites montana* (3). The vigor of the *montana*, its productivity as described by Webster (18), and its habit of late blooming are highly desirable characteristics, which if combined with the cold resistance of *Aleurites Fordii* would result in superior tung trees for the southern United States. The Florida Agricultural Experiment Station early attempted hybridization of the two species, but unfortunately all of the resulting trees have been practically sterile. Further work along this line has been attempted by the United States Department of Agriculture (14). At the Experimental Tung Farm, some of these hybrids, now 6 years old, were in full bloom on May 6, 1947, whereas trees of *Aleurites Fordii* has reached the peak of bloom by April 15. Most of these trees bear staminate flowers only, but one or two are fruitful. Back-crosses to the *Aleurites Fordii* are hopefully being made.

The selected seedlings and new varieties of budded tung trees are receiving an enthusiastic reception from the tung growers. Budded varieties were not officially released for commercial distribution until November, 1947, but many growers have obtained buds and nursery stock under agreements for cooperative testing. At present most of the orchards are being planted with selected seedlings. Each year there is a limited amount of first generation seed of Isabel (L–2) and LaCrosse (F–99) at the Experimental Tung Field, Poplarville, Mississippi. The demand for this seed is always many times greater than the supply, and orders are always placed months in advance of harvest. One almost has to be a polished diplomat in order to distribute the seed fairly and still retain the friendship and good will of the ever important taxpayer.

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Response of Peach Trees to Boron[1]

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ONE of the most serious problems of commercial peach production in the Sandhills region of North Carolina has been the loss of vigor and subsequent short life of the trees. This condition is possibly related to a deficiency of one or more nutrient elements.

The sandy soils of this region are low in natural fertility and in the capacity to retain applied nutrients. Response to applications of nitrogen, phosphate and potassium have frequently been disappointing. Boron is one of several elements that have been tested as supplements to the usual fertilizer practices. It has been used effectively in this region on apples, grapes and alfalfa (5, 9).

METHODS

The experiment was conducted in an orchard of vigorous, 6-year-old trees of the Georgia Belle variety. Five similar plots were used, each consisting of nine rows of seven trees. Each plot received the following treatments: From 1938 to 1940, one row received ¼ pound borax annually, four rows ⅛ pound, and four rows none. After 1940 borax applications were discontinued on some of the borax rows, and started on others as shown in Table I. Three different lime treatments were used. However, since none of the tree measurements indicate a relation to calcium treatments, no discussion of this factor is included here. The average pH for the topsoil in this orchard was 6.0.

TABLE I—BORAX TREATMENTS — AMOUNT APPLIED TO EACH TREE IN EACH ROW FROM 1938 TO 1944 (POUNDS)

Year	Row 1	2	3	4	5	6	7	8	9
1938	¼	⅛	⅛	⅛	⅛	0	0	0	0
1939	¼	⅛	⅛	⅛	⅛	0	0	0	0
1940	¼	⅛	⅛	⅛	⅛	0	0	0	0
1941	¼	⅛	0	⅛	0	0	0	0	⅛
1942	¼	⅛	0	0	⅛	0	⅛	0	0
1943	¼	⅛	0	0	⅛	0	⅛	0	0
1944	¼	⅛	0	⅛	⅛	0	0	0	0

Individual tree records of growth, foliage condition and bloom were taken for all trees in the five blocks. Detailed records of harvest, shoot growth, fruit buds and samples for chemical analyses were taken from two trees in each row in each plot.

EFFECTS OF BORAX APPLICATIONS ON FRUITING

Early Ripening of fruit on borax-treated trees was the first effect observed and occurred each year. It was most pronounced with the ¼ pound annual rate. Usually, fruit on these trees had ripened before

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the first picking on untreated trees. Data for the 1/8 pound rate shown in Fig. 1 indicate that the earlier ripening was related to applications of the current season. However, there was a slight effect from repeated applications of previous years. Data for succeeding years showed a similar relation of borax application to time of maturity of the fruit.

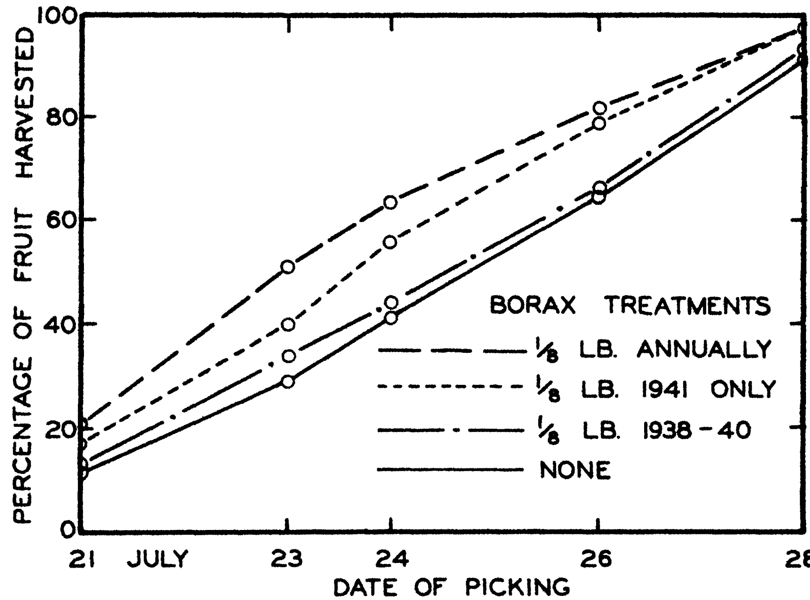

FIG. 1. Time of ripening of Georgia Belle peaches from borax treated trees in 1941. All fruit from the 1/4 pound treatment had been harvested before the period shown.

Yields were not measured in detail until 1941 because no pronounced effects had been observed earlier. In 1941 and 1942 fruit from the sample trees was weighed and counted at each picking. In 1943 the entire crop was killed by a late freeze. In 1944 individual tree yields were estimated by two observers before harvest. In 1945 fruit was counted on the trees before harvest, and the fruit of the individual trees from three of the treatments from one major picking was run over a mechanical grader.

As shown in Table II the relation between borax applications and fruit yields varied from year to year. Yields were smaller on borax-treated trees in 1941 and 1944, but greater in 1942 and 1945. The low yields on untreated trees in 1942 were due to poor fruit bud formation of the previous season. In 1944, the trees that had received borax in previous years bloomed late and were more severely injured by a late frost than the untreated trees that bloomed earlier. Thus, while there was a relation of yields to borax application in these years, this relation was indirect and operated through other responses in the tree.

TABLE II—YIELD OF PEACH TREES IN RELATION TO BORAX APPLICATIONS

Borax Treatment	Average Number of Fruit Per Tree			
	1941	1942	1944	1945
¼ lb annually	164*	442	157	915
⅛ lb annually	569	782	405	834
⅛ lb 1938–1940	641	603	473	—
⅛ lb current season only	802	333	—	—
None	773	364	570	743
L.S.D. at 5 per cent level	132	168	196	n.s

*Ripened very early and a few fruit may have been lost.

Fruit Size was greater each year for trees receiving ¼ pound of borax, and in 1941 and 1945 on trees receiving ⅛ pound as shown in Tables III and IV. In 1942 the large fruit on untreated trees was due to the very low yields of this treatment. The graphs in Fig. 2 indicate that in 1941 the fruit size on all untreated trees was about the same regardless of tree yield. In contrast to this, the fruit on trees with a comparable number of peaches but receiving borax in previous years was larger and decreased in size as the tree load increased. Fruit size of trees receiving borax for the first time during the current season was similar to that of untreated trees, indicating that size of fruit was not affected the first year by borax applied in the late winter. Similar effects on fruit size from borax were found in 1945.

TABLE III—SIZE OF FRUIT IN RELATION TO BORAX APPLICATIONS

Borax Treatment	Average Weight Per Fruit (Pounds)		
	1941	1942	1945
¼ lb annually	0.269	0.253	0.227
⅛ lb annually	0.228	0.183	0.202
⅛ lb 1938–1940	0.209	0.184	—
⅛ lb current season only	0.168	—	—
None	0.168	0.220	0.194
L.S.D. at 5 per cent level	0.020	0.024	0.026

Fruit Quality as indicated by color was reduced by the annual application of ¼ pound of borax. There was a reduction in the red coloration and the under color was white or creamy-white in comparison with the greenish-white of normal fruit of this variety. This under color made it difficult to judge picking ripeness from appearance of fruit. The flavor of fruit from the heavier borax treatments was slightly insipid, similar to that of fruit picked green and ripened in storage. This was due possibly to lower acidity.

TABLE IV—CLASSIFICATION BY SIZE OF PEACHES FROM DIFFERENT BORAX TREATMENTS FOR JULY 13, 1945 HARVEST (PER CENT)

Borax Treatment	Above 2½ Inches	2¼ to 2½ Inches	2 to 2¼ Inches	1⅞ to 2 Inches
¼ lbs annually	19.4	51.9	24.7	4.0
⅛ lbs annually	7.1	34.0	43.2	15.7
None	3.6	31.4	42.6	22.5
L.S.D. at 5 per cent level	n.s	7.10	14.23	9.09
Average weight per fruit	0.293	0.230	0.184	0.151

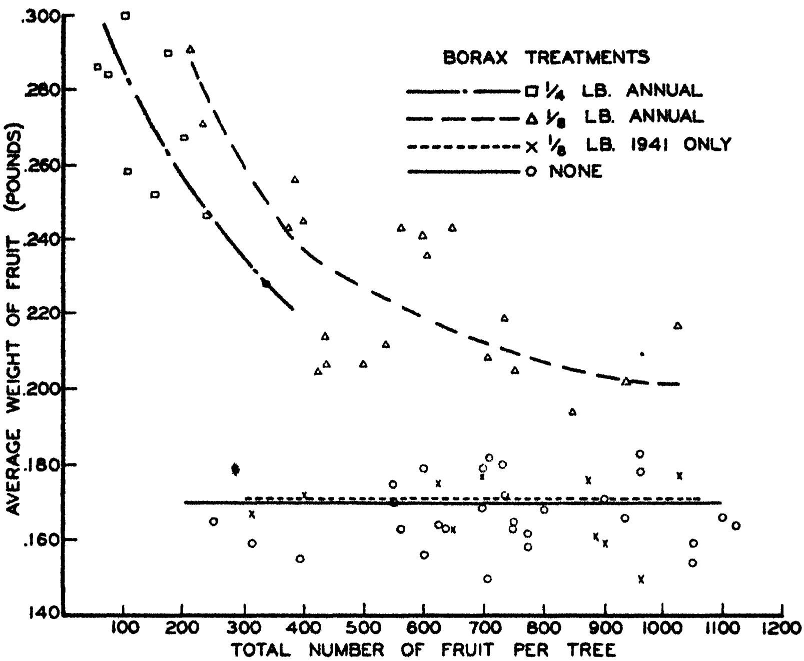

FIG. 2. Average size of fruit in pounds in relation to the total number of peaches per tree in 1941 of Georgia Belle trees receiving different annual amounts of borax. Lines drawn in indicate a trend to a greater relation of fruit size to tree load for trees receiving borax in previous years in addition to larger size as compared with fruit from untreated trees. A similar response was found in 1945.

The texture of fully ripe fruit was somewhat softer and more mealy, but there was no pulling away or browning at the pit. Fruit from borax-treated trees kept as well in a household refrigerator as that from untreated trees. It was acceptable to most palates and was considered inferior only when compared with normal fruit from untreated trees. The ⅛ pound rates of borax produced only very slight effects on these fruit qualities.

Time Of Bloom was delayed by borax applications in 1942 and 1944. In the early spring of 1942 the flower buds were less advanced on trees to which borax had been applied, especially those receiving annual applications, as shown in Table V. In 1944 weather conditions were such that the period of bloom for all varieties of peaches in the Sandhills was prolonged and differences between borax treatments were pronounced. On March 23, untreated trees were rated as being in 90 per cent of full bloom, those that had received ⅛ pound of borax the previous year as 30 per cent and those that had received ¼ pound as only 14 per cent. On April 4 the untreated trees had passed full bloom and set fruit, whereas borax-treated trees were just in full bloom. Some delay in bloom was noted for most trees that had re-

TABLE V—DELAY IN FLOWER BUD DEVELOPMENT OF PEACH TREES RECEIVING BORAX (MARCH 26, 1942)

Borax Treatment	Total No. Trees Observed	Trees Showing Delay in Buds	
		Number	Per Cent
¼ lb annually	8	7	87.5
⅛ lbs annually	87	51	58.6
⅛ lbs 1941 only	33	3	9.1
⅛ lbs 1938–1940	64	4	6.6
None	165	2	1.2

ceived as much as ⅛ pound of borax any time in the previous four years.

A similar condition was evident in a block of 80 Hiley Belle trees, half of which had been given ⅛ pound of borax in 1942 and in 1943. The night after the full bloom of the treated trees the temperature dropped below freezing, and much of this late bloom was killed, while the fruit that had set on untreated trees escaped with slight damage. The result of this is shown in the yield record of that year. A similar delay in bloom could not be observed in 1945 or 1946, but weather conditions were such that the period of bloom was shorter.

EFFECTS OF BORAX APPLICATIONS ON GROWTH

Resistance To Defoliation was the most conspicuous vegetative response to borax, but was observed only in 1941. This defoliation was due to spray injury but was probably associated with weather conditions. On July 1, the average ratings of defoliation on trees that had received ¼, ⅛ and 0 pounds of borax were 10, 30, and 80 per cent, respectively. Differences between treatments at the end of harvest August 1 were found to be smaller but were still evident. Defoliation in 1942, while severe, was general throughout the orchard and showed no relation to borax treatments. There was little or no defoliation in the succeeding years of the experiment. Tests with hand spraying in 1943 failed to produce injury on either treated or untreated trees.

Terminal Growth Measurements (Table VI) show small differences with borax treatments. These differences were larger in 1941 than in following years and are probably more related to the defoliation of that year than to borax treatment. In 1941 terminal shoots on untreated trees were longer but smaller in diameter (as indicated by weight per inch) and had fewer fruit buds per inch. These responses are similar to those on defoliated trees (7, 8).

The fruit bud counts for 1941 agreed with estimates of the percentage of full bloom made in the spring of 1942 which were 75, 50 and 10 per cent for the ¼, ⅛ and 0 pound borax treatments, respectively. Thus the lower yields of untreated trees in 1942 were due to the failure of these trees to set fruit buds because of premature defoliation rather than directly due to the borax treatments. Differences between treatments were small and inconsistent in 1942 and 1943.

Chemical Analyses for total nitrogen and total carbohydrates of terminal shoots in 1941 (Table VII) show differences that also are

TABLE VI—MEASUREMENTS OF TERMINAL SHOOTS FROM TREES RECEIVING BORAX

Borax Treatment	Average Length (Inches)	Weight Per Inch (Grams)	Fruit Buds Per Inch (Number)
1941			
¼ lbs annually	17.58	0.528	0.859
⅛ lbs annually	17.47	0.409	0.599
⅛ lbs. 1938–40	18.34	0.406	0.549
⅛ lbs 1941 only	20.31	0.387	0.263
None	19.39	0.363	0.254
L.S.D. at 5 per cent level	1.83	0.054	0.140
1942			
¼ lbs annually	19.9	0.51	1.10
⅛ lbs annually	15 8	0.38	0.99
⅛ lbs 1942 only	16.8	0.45	1.22
None	14.6	0.41	1.08
L.S.D. at 5 per cent level	0.95	0.03	n.s
1943			
¼ lbs annually	21.83	0.521	1.42
⅛ lbs annually	19.89	0.479	1.54
⅛ lbs 1942–43	19.48	0.505	1.55
None	19.95	0.500	1.69
L.S.D. at 5 per cent level	n.s	n.s	0.15

probably more related to the differences in defoliation than directly to borax treatment. The shoots from the high borax treatment were highest in carbohydrate in July, and this treatment showed the least defoliation. On the other hand, shoots from the check treatment were highest in nitrogen, and these trees were making active length growth associated with the defoliation. These differences in percentages of carbohydrate and nitrogen in relation to borax treatment were reversed at the beginning of dormancy. No differences in percentage of total nitrogen in terminal shoots of the different treatments were found in 1942 or 1943.

TABLE VII—TOTAL NITROGEN AND TOTAL CARBOHYDRATES IN TERMINAL SHOOTS FROM PEACH TREES IN RELATION TO APPLICATIONS OF BORAX

Borax Treatment	Jul 17, 1941	Oct 29, 1941	Dec 30, 1942	Dec 14, 1943
Total Nitrogen (Per Cent of Dry Weight)				
¼ lb annually	0.925	0.812	0.778	0.802
⅛ lb annually	0.994	0.596	0.851	0.823
⅛ lb 1938–1940	1.020	0.628	—	—
⅛ lb current season only	1.060	0.536	0.792	0.867
None	1.170	0.566	0.821	0.872
L.S.D. at 5 per cent level	0.11	0.067	0.052	n.s
Total Carbohydrates (Per Cent of Dry Weight)				
¼ lb annually	27.93	31.71	—	—
⅛ lb annually	26.63	32.78	—	—
⅛ lb 1938–1940	26.20	32.87	—	—
⅛ lb current season only	24.44	33.43	—	—
None	24.69	33.94	—	—
L.S.D. at 5 per cent level	1.11	0.81	—	—

Trunk Circumference measurements were taken of all trees during each dormant season, but no differences were found in relation to borax treatment.

Injury from Borax

Two adjacent trees receiving ¼ pound of borax annually, were severely injured in 1941, and a few adjoining trees receiving the ⅛ pound rate showed some damage. The injury consisted of a dieback of the terminal shoots in early summer, and later many small shoots were produced below the injured region. Similar injury occurred on 2-year-old Redelberta trees in another block which had received 1.4 ounces of borax per tree applied in an area 5 feet in diameter around the trees. The injury resembled the dieback of apple reported for boron deficiency (1).

In an attempt to find the tolerance of peach trees to borax, applications varying from ⅛ to 1 pound per tree were applied in 1942 to paired trees just outside the experimental plots. However, no injury to vegetative growth was produced from this single application even at the 1 pound rate.

Discussion

From the data presented, it seems inadvisable to draw any conclusions of a direct relationship between borax treatments and yield of fruit. The heavier set of fruit in 1942 from better fruit bud formation and the smaller crop in 1944 resulting from frost injury seem to be indirect effects. There is the possibility of an influence on fruit setting, and on physiological drop after setting. Scott (5) found a pronounced effect of borax treatments on the yield of certain varieties of grapes in this same region, but was unable to determine how this effect was produced.

The response of larger fruit, especially with the heavier rate of borax, was very noticeable. The greater relation between number of fruits per tree and fruit size of trees receiving borax may offer a clue for the absence of decided response to fruit thinning in this area except where the degrees of thinning have been extreme. This response may be related to factors of translocation and metabolism associated with boron. It may be due to an effect similar to very early thinning or blossom thinning which would have a greater influence on fruit size than usual thinning practices.

Early ripening and lowering of color intensity of fruit from treated trees were observed every year. The earlier maturity at least, may have been due to injury factors, especially as it was more pronounced on trees receiving the heavier application, and was associated with applications of the current season. This effect might have been reduced had the borax been applied at another time of the year, as in the fall.

Haller and Batjer (2) were doubtful whether the earlier dropping of Jonathan apples on trees receiving borax was due to an advancement of maturity of fruit. They also found an earlier development of red and ground color with borax applications. Heinicke (3), on the

other hand, reports a decided lessening of preharvest drop of McIntosh apple where borax was applied to borax-deficient trees.

The delay in bloom in 1944 was definitely associated with borax application, although the length of the period of bloom was influenced with climatic conditions. It may indicate an intensified rest period or a lower response to periods of warm weather during dormancy. A differential damage from late frosts in relation to the time of bloom such as occurred in 1944 may have been a factor affecting yields in other years, although not great enough in itself to have been observed.

No explanation is suggested for the resistance to defoliation or spray injury observed in 1941 on trees receiving borax. Measurements and chemical analyses of terminal shoots and fruit bud counts indicate a relation to each other and to foliage retention. Boron has been shown to have an effect on carbohydrate accumulation and translocation and on nitrogen assimilation (4). If the trees in this investigation were deficient in boron, such factors may have influenced the foliage and growth differences found, but have been most conspicuous in foliage retention.

Summary

Applications of borax were made to bearing Georgia Belle peach trees in the Sandhills region from 1938 to 1945. The rates used were 1/8 pound and 1/4 pound per tree applied about March 1.

Earlier ripening of fruit occurred each year and was more pronounced at the 1/4 pound annual rate, and in the year application was made.

Size of fruit was larger, especially at the 1/4 pound rate. Applications of the current season had little effect on size, the response developing the second year or from repeated applications.

Fruit size of trees receiving borax showed a relation to tree load, whereas that of untreated trees did not.

Fruit quality as shown by color, texture and flavor was slightly lower for trees receiving 1/4 pound borax annually.

Full bloom was delayed by borax treatment about 10 days in 1944 and was associated with weather conditions. This response could not be found in other years, although the swelling of fruit buds was delayed in 1942.

Less defoliation had occurred by July 1 on borax-treated trees in 1941 only. This retention of foliage was followed by better shoot growth and heavier set of fruit buds which influenced yields the following year.

Yields were variable and were related to the effects of borax on the retention of foliage and fruit bud set in 1942 and to the time of bloom and frost injury in 1944.

Borax injury occurred on a few trees and consisted of dying back of the terminal shoots, followed by the development of many small shoots below the injured region.

Rates of 1/8 pound per tree seemed to be close to the tolerance of these trees.

The original objectives of the study of the relation of boron to vitality and longevity of the tree were not attained.

Borax in smaller amounts or at less frequent intervals, or applied in the fall might lessen the danger of injury and under conditions similar to those of the experiment be of economic value.

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Effect of Different Seedling Rootstocks on Growth, Production, and Nutrient Absorption of Tung Clones

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Tung orchards in the United States are composed almost entirely of seedling trees. With other major tree crops it has been found profitable to select and propagate desirable clones. Work on selection of promising individual seedling tung trees was begun in 1938 by the United States Field Laboratories for Tung Investigations, and tung clones were propagated, beginning in 1939, from a few outstanding trees. Only miscellaneous seedling rootstocks were available at first. In 1939 and in 1940 open-pollinated seedlings from more than 400 different seed trees were grown in the nursery, and it was found that the different seedling progenies varied widely in vigor, type of growth, and degree of uniformity. To date no attempt has been made to propagate clonal rootstocks for tung, but the wide and consistent differences observed in the seedling progenies in the nursery suggested that some might well be better suited for use as rootstocks than others.

Materials and Methods

In 1941 buds of six clones were budded on rootstocks grown from open-pollinated seed of eight parent trees: A–36, F–2, F–547, F–551, F–553, G–40, L–99, and L–101,[1] selected on the basis of vigor of the seedlings in the nursery, or in some cases on the basis of characteristics of the parent tree. The clones F–571, G–40, G–46, L–2, L–14, and M–2, used as scions, were selected wholly on the basis of the promise of the parent trees, since at that time no performance records of the budded tung trees were available. The six clones differ widely in growth habit, manner of fruit production, date of bloom, and other characteristics, and thus as a group they are fairly representative of the present varieties of tung *(Aleurites fordii)*. In 1942 trunk diameter measurements of the budded trees were taken and they were transplanted to an orchard near Lloyd, Florida. The trees were budded low so that the point of union after transplanting was at or near the ground line.

In setting up the experiment a split plot design (7) was used in which the main plots consisted of three replications of the six scion clones in randomized block design. Each of the scion main plots consisted of 16 trees, two on each of the eight types of rootstocks (in a few cases only one tree was available of certain rootstocks). This design afforded the maximum precision for rootstock effects and their interactions with the scion varieties, but with some sacrifice in precision for comparisons between the different clones. All trees were

[1]Tung tree selections are designated by a serial number combined with an initial representing the State in which the original tree was found, A for Alabama, F for Florida, G for Georgia, L for Louisiana, M for Mississippi.

trained to a vase form with a 30-inch trunk. All the main foundation branches that grew were allowed to remain.

With regard to soil types, the greater part of replication I was set out in level sandy bottom land, classified as Norfolk fine sand. All of replication III and the major part of replication II were planted on the adjacent side slope, the soil being much heavier and classified as Red Bay fine sandy loam. The land was terraced at the time of planting, but previously most of the top soil from a few small local areas had been lost by erosion.

Observations over the 5-year period from 1942 to 1946 indicate that rootstocks have a definite influence on several tree characteristics, and records have been taken of: (a) the number of primary structural branches forced out along the scion trunks; (b) cross-sectional area increase for 1942 to 1944; (c) presence of overgrowth, indicating possible lack of congeniality; (d) air-dry weights of leaf blades (1946); (e) percentages of nitrogen, potassium, calcium, and magnesium in dry weight of leaves (1946); (f) fruit yields for 1942 to 1946, inclusive; and (g) air-dry weights of individual fruits.

It became increasingly difficult, year by year, to obtain accurate data on trunk circumference, owing to the tendency to force out low branches at or near the point of measurement. The variety G–40 suffered considerable limb breakage in 1943, which increased the tendency to force out low branches in 1944. Hence circumference measurements were abandoned in 1944 on G–40, and in 1945 on the other five varieties.

Scores for overgrowth were made on a numerical scale ranging from 1, representing a tree apparently normal, to 4, representing a rather serious overgrowth of stock or scion.

Leaf samples for weight and mineral content determinations were taken during the first week of October 1946, from median positions on shoots of average length in representative positions on four sides of each tree. In each replication one sample of 60 leaves was taken from each variety on each rootstock, excluding the rootstocks A–36 and L–101.

Results

The effects of the different rootstocks on average performance of the clones attained statistical significance at the .001 level of probability for (a) number of primary branches; (b) cross-sectional area of trunk in 1942, one year after budding; (c) gain in cross-sectional trunk area 1942 to 1944; (d) score for overgrowth; (e) the magnesium and the potassium content of the leaves (Table II); and (f) total yield of air-dry fruit (Table I). Differences in weight of leaves (Table I) and in nitrogen content of the leaves (Table II) attained statistical significance at the .01 level of probability. The rootstock had relatively little influence on weight of each fruit or on the phosphorus and the calcium content of the leaves, the differences attaining statistical significance only at the .05 level. The validity of the data on leaf composition is supported by the results of less extensive series of analyses made in 1944 and in 1945, and also by the incidence of visi-

TABLE I—INFLUENCE OF ROOTSTOCK ON TUNG TREE CHARACTERISTICS, YIELD, AND SIZE OF FRUIT*

Rootstocks	1942 Cross-Sectional Area of Scion Trunks at Transplanting (Sq Cm)	Gain in Cross-Sectional Area of Trunks 1942-1944 (Sq. Cm)	Primary Branches Per Tree (Number)	Overgrowth at Bud Union† (Rating)	Dry Weight Per Leaf Blade (Grams)	Total Yield Air-Dry Fruit Per Tree 1943-1946 (Pounds)	Average Air-Dry Weight Per Fruit (Grams)
A-36	7.29	41.8	7.07	1.69	——	30.0	—
F-2	7.23	52.7	7.13	1.44	2.272	38.0	29.4
F-547	5.61	35.1	5.93	2.30	2.069	26.2	28.6
F-551	3.11	40.5	5.90	2.28	2.117	26.9	28.9
F-553	3.79	34.6	5.33	1.53	2.130	25.0	28.2
G-40	6.01	45.3	6.23	1.44	2.004	32.6	28.9
L-99	6.55	49.9	7.13	1.25	2.232	34.5	29.4
L-101	6.36	38.3	6.37	1.72	——	27.5	—
F found	7.57	6.89	5.20	4.97	3.3	4.49	2.36
F Sig. at .05	2.14	2.14	2.14	2.12	2.3	2.12	2.37
F Sig. at .01	2.91	2.91	2.91	2.87	3.3	2.87	—
F Sig. at .001	4.37	4.37	4.37	4.37	——	4.37	—
L.S.D. at .05	1.72	7.1	0.82	0.49	0.191	3.04	0.82
L.S.D. at .01	2.29	9.4	1.09	0.65	0.255	4.03	—
L.S.D. at .001	2.98	12.3	1.42	0.85	——	5.29	—

*Averages for six clones, F-571, G-40, G-46, L-2, L-14 and M-2, except cross-sectional area of trunks, which is based on five clones, omitting G-40.
†On scale from 1.0 for normal union to 4.0 for marked overgrowth.

TABLE II—INFLUENCE OF ROOTSTOCK ON NITROGEN AND MINERAL CONTENT OF LEAVES, DRY BASIS (1946)*

Rootstock	Nitrogen (Per Cent)	Phosphorus (Per Cent)	Potassium (Per Cent)	Calcium (Per Cent)	Magnesium (Per Cent)
F-2	1.90	0.17	0.88	2.61	0.27
F-547	1.77	0.15	0.85	2.67	0.28
F-551	1.76	0.15	0.91	2.52	0.24
F-553	1.76	0.17	0.92	2.80	0.26
G-40	1.72	0.16	0.86	2.78	0.35
L-99	1.81	0.16	0.85	2.64	0.29
F found	4.08	2.44	4.84	2.38	9.56
F Sig. at .05	2.37	2.37	2.37	2.37	2.37
F Sig. at .01	3.34	—	3.34	—	3.34
F Sig. at .001	4.76	—	4.76	—	4.76
L.S.D. at .05	0.09	0.012	0.04	0.20	0.03
L.S.D. at .01	0.11	—	0.05	—	0.04
L.S.D. at .001	0.16	—	0.07	—	0.05

*Data are averages for six clones, F-571, G-40, G-46, L-2, L-14, and M-2. Samples of midshoot leaves collected first week in October 1946.

ble deficiency symptoms. A score for nitrogen deficiency in 1946 based on leaf color showed highly significant differences due to rootstock. Trees on F–2 rootstock had the best color, and those on G–40 rootstock the poorest color. Both foliar analysis and foliage symptoms indicate differences in absorption of elements, depending upon the rootstock used.

It was previously pointed out that the design of this experiment was such as to permit of the comparison of clones with a relatively low degree of precision, yet the data in Table III show that the varieties used differ significantly, (a) in number of primary branches, (b) in tendency to form overgrowths, (c) in dry weight of leaves, (d) in yield of fruit, and to an extreme degree, (f) in size of fruit. Except for

TABLE III—INFLUENCE OF SCION VARIETY ON TREE CHARACTERISTICS, YIELD, SIZE OF FRUIT, AND NITROGEN AND MINERAL CONTENT OF LEAVES, DRY BASIS*

Scions	1942 Cross-Sectional Area of Scion Trunk† (Sq Cm)	Primary Branches Per Tree† (Number)	Overgrowth at Bud Union† (Score)	Air-Dry Weight of 100 Leaves (Grams)	Total Yield Air-Dry Fruit Per Tree 1943–1946 (Pounds)	Average Air-Dry Weight Per Fruit (Grams)	Nitrogen in Leaves Dry Basis (Per Cent)	Potassium in Leaves Dry Basis (Per Cent)	Calcium in Leaves Dry Basis (Per Cent)	Magnesium in Leaves Dry Basis (Per Cent)
F-571	6.0	7.4	1.73	190 8	28.7	25.6	1.93	0 96	2.64	0.26
G-40	—	—	2.42	191.5	20.9	23.7	1.80	0.96	2.29	0.22
G-46	6.6	5.9	1.42	207.0	32 9	33.7	1.76	0.81	2.76	0.29
L-2	6.97	6.2	1.83	230.3	30 0	30 9	1.65	0.83	2.74	0.31
L-14	6.87	5.7	1.56	224.5	29.7	30.0	1.79	0.85	2.72	0.29
M-2	7.95	6.7	1.29	248.5	38.3	29.1	1.79	0.86	2.88	0.33
F found	—	15.82	5 54	7 17	3 28	34.08	—	—	5.48	—
F Sig. at .05	—	3.84	3.33	3.33	2.81	3.33	—	—	3.33	—
F Sig. at .01	—	7.01	5.64	5.64	4.34	5.64	—	—	5.64	—
F Sig. at .001	—	14.39	—	—	—	10.48	—	—	—	—
L.S.D. at .05	—	0.65	0.53	27.1	13 95	1.94	—	—	0.24	—
L.S.D. at .01	—	0.86	0.76	38.5	19.84	2.76	—	—	—	—
L.S.D. at .001	—	1.42	—	—	—	3.99	—	—	—	—

*Averages for six rootstocks, F-2, F-547, F-551, F-553, G-40, and L-99, except as indicated in note †.
Samples of midshoot leaves collected first week of October 1946.
†Averages for eight rootstocks, including A-36 and L-101, in addition to those listed in note *.

calcium content, the clones seemed to differ little in leaf composition. Although interactions between rootstock and scion would be expected (for example, one scion variety might have a tendency to form overgrowths with certain rootstocks and not with others), the statistical analysis failed to support with reasonable odds such variations as were observed.

Rootstocks influenced the "force out" of primary branches, possibly in large measure through their influence on size of nursery tree. Trees having large cross-sectional area at transplanting seemed to produce the most branches. However, many factors other than rootstock influenced size of the tree at transplanting. Each subplot in the experiment consisted of two trees of one rootstock-scion combination. In most cases the original cross-sectional area of one of the two trees was greater than the other. The average combined total yield per tree for 1945 and 1946 on a field-weight basis was 2.05 pounds more for the trees larger when transplanted than for the smaller trees, a difference of 17 per cent, supported by statistical significance at the .01 level. It is possible that these differences in size of nursery trees and in yields for trees having the same rootstock were due to hereditary differences in open-pollinated seedling rootstocks.

Clones on F–2 rootstocks gave the greatest yields, made the largest gains in cross-sectional area, had the highest number of primary structural branches, produced the largest fruits, had a very good con-

geniality score, and produced the heaviest leaves with the highest percentage of nitrogen and phosphorus. Potassium, calcium, and magnesium content of leaves were the only factors ranging from fair to poor. Trees on rootstocks F–551 and F–553 consistently produced lower yields than trees on other rootstocks. Lack of congeniality between rootstock and scion had a direct bearing on fruit production; the greater the growth contrast, the smaller the yields. The correlation coefficient between overgrowth score in 1947 and total fruit production 1943 to 1946 for 144 subplots gave the highly significant value of —.462 where ±.321 is significant at the .001 level. By using the same subplots a correlation of +.463 was found between yields and the N/K ratio in the leaves. This signifies that the higher the nitrogen content and the lower the potassium content of the leaves, the better were the yields. Nitrogen has apparently been a most important factor in fruit production. Since the trees were under uniform culture and fertilization, variations in nutrient uptake are attributable largely to rootstock or clone.

That rootstocks can differ in their capacity to absorb mineral nutrients from the soil has been recognized for some years by several English investigators working with apple rootstocks (2, 3, 4, 5, 6). More recently Goodall (1) found that apple leaves from varieties on a vigorous rootstock (M XII) contained less calcium and more magnesium than the leaves from the same varieties on a dwarfing rootstock (M IX). The work with tung trees reported here affords clear evidence of the effect of rootstocks on the accumulation of certain nutrient elements in the leaves and an associated influence on productivity.

Interestingly enough, a significant correlation was found to exist between fruit production and the sum of milli-equivalents of calcium plus the milli-equivalents of magnesium. Using the 144 subplots, a correlation of +.299 was found, where ±.254 is necessary for significance at the .01 level and ±.321 at the .001 level. In addition M–2, the clone leading in fruit production, had the largest percentage of calcium and of magnesium in the leaves; G–40, the clone with the poorest production record, had the lowest percentage of calcium and of magnesium in the leaves. However, in the case of the G–40 clone, a certain amount of limb breakage due to overproduction occurred the first crop year (1943). G–40 trees on L–99 and F–553 rootstocks produced the least fruit and suffered least breakage. How much this breakage has influenced subsequent growth and production is not known.

It is not claimed that the rootstocks and scions used in this preliminary test are the best available. The results do emphasize the necessity of using rootstocks of proven performance. Much more extensive rootstock-scion experiments are under way at the several United States Department of Agricultural Tung Laboratories.

Summary and Conclusions

Rootstocks have a definite influence on tree and fruit characteristics. A statistically significant influence of rootstock has been demon-

strated for: (a) the number of primary branches forcing out along the trunk, (b) cross-sectional area increases of trunks, (c) overgrowths at bud union, (d) percentage of nitrogen, phosphorus, potassium, calcium, and magnesium in leaves, (e) yields of fruit, (f) dry weights of leaves, and (g) air-dry weights of individual fruits.

Independently the clones used differed significantly in: (a) number of primary branches forcing out from the initial trunk, (b) overgrowths at the bud union, (c) dry weight of leaves, (d) percentage of calcium in the leaves, and (e) yield of fruit. No statistically significant interactions or specific cases of congeniality or lack of congeniality between clone and rootstock were observed.

Highly significant correlations existed between high fruit production and low (favorable) overgrowth score, and between high fruit production and high N/K ratio in the scion leaves.

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Notes on the Growth of Persian Walnut Propagated on Rootstocks of the Chinese Wing-Nut Pterocarya Stenoptera

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Although the Persian walnut is commonly and successfully grown on seedlings of both the Northern California black *Juglans hindsii* and of *J. regia,* there are certain disorders which suggest that other rootstocks might be desirable (1, 2). The walnut girdle disease "Black Line" is thought to occur when certain horticultural varieties of *regia* are grafted on rootstocks of *J. hindsii* and its hybrids. Seedlings of the Persian walnut are very susceptible to mushroom root rot and varieties propagated upon them have been recommended for planting only on soils free of this disease. This situation has created an interest on the part of walnut investigators in the behavior of the Persian walnut when propagated on other stocks.

In 1938, tests were initiated at the United States Plant Introduction Garden at Chico, California, to evaluate seedlings of several Persian walnut introductions. The Chinese wing-nut, *Pterocarya stenoptera,* was introduced in 1924 under P. I. 61938 (Fig. 1). The genus *Pterocarya* is somewhat similar to the genus *Juglans* except for its small winged nutlets produced in racemes 8 to 10 inches long. Since

Fig. 1. *Pterocarya stenoptera* trees growing near Hsing Yo Ping, Hupeh, China. Photo by Frank N. Meyer, 1917.

FIG. 2. Sorrentina walnut (P. I. 33189) on *Pterocarya stenoptera* rootstock. Tree approximately 25 feet high at end of eight season's growth. Photo taken at U. S. Plant Introduction Garden, Chico, California, April 1948.

these genera belong to the same family, *Juglandaceae,* seedlings of *P. stenoptera* were included in rootstock tests.

Pterocarya stenoptera is one of the commonest trees on river banks and on stony and sandy beds of summer torrents in Hupeh and Szechwan, China, up to 1000 m altitude. On the Yangsze River and its main tributaries, it is the first tree to appear an newly formed islands.

It is a quick-growing tree, attaining a height of from 25 to 30 m and a girth of from 4 to 6 m with massive spreading branches and thick, deeply fissured gray bark. Young plants spring from the roots and frequently form thickets on dry, stony or sandy river beds (3). Rehder places this species in his climatic Zone VI, which runs from Long Island southward through Maryland, Virginia and Kentucky to New Mexico, then gradually northward through parts of California, Oregon and Washington (4).

Several buds of the Sorrentina Persian walnut, P. I. 33189, a variety introduced from Italy in 1912, were set on this stock in the summer of 1938 and later three buds of three Persian walnut seedlings, progeny of cold hardy trees in Poland, were worked on it. The Sorrentina trees were approximately 30 inches high at the end of their first season's growth in the nursery, and those of the walnut seedlings of Polish origin attained a height of from 24 to 36 inches, the majority measuring 30 inches. These same seedlings propagated on *Juglans hindsii* roots averaged 42 inches in height. One of the walnut seedlings from Poland, propagated on *Pterocarya stenoptera,* was sent to Michigan. It made a fair growth in its first season in the orchard.

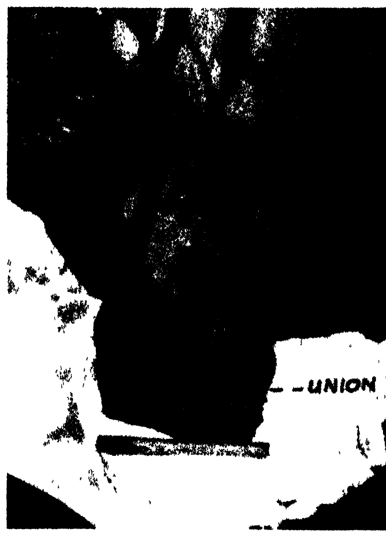

FIG. 3. Union of scion of Sorrentina variety of walnut with *Pterocarya stenoptera* root after eight season's growth. Photographed at U. S. Plant Introduction Garden, Chico, California May 1948.

Of the several seedlings of *Pterocarya stenoptera* budded with *Juglans regia* at Chico in 1938, one budded to the Sorrentina variety was planted in the orchard in the spring of 1940 and has been allowed to grow to maturity (Fig. 2). Another tree of this same variety, but propagated on *J. hindsii* was planted in the same orchard in the spring of 1934. The average yearly circumference growth of these two Sorrentina trees, one with eight and the other with 14 growing seasons, compares closely for both scion and rootstock. Growth on both species of roots has been rapid and thrifty, and the slight difference observable is in favor of the younger tree on *P. stenoptera.* Overgrowth is in favor of roots in each case, but is considerable less on *P. stenoptera* (Fig. 3). The average yearly increase of rootstock over scion is only .28 inch on *P. stenoptera* as against .41 inch on *J. hindsii.* This would seem to indicate that in this one instance *P. stenoptera* roots are sufficiently compatible with *J. regia* to make use of the assimilates transported to them.

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Relative Variability of Fruits of Seedling and Budded Tung Trees

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THE approximately 200,000 acres of tung orchards in the tung belt of the southern United States consist almost entirely of seedling trees. The best of the present commercial orchards have been developed by growers who have practiced mass seed selection. By this method seed gathered from a number of the highest producing trees is planted as one lot. Although orchards grown from such mass selected seed are better than those grown from unselected seed, the best commercial seedling orchards show a very great variability between individual trees with respect to size, habit of growth, and type of foliage. It is also apparent that there are great variations in the size, shape, quantity, and quality of the fruit produced.

Two means of reducing this variability are possible: (a) by the vegetative propagation of the most promising seedlings; and (b) by growing seedlings of so called "progeny tested" trees, that on the basis of previous tests have been found to produce a uniformly good progeny. This raises the question as to how closely the most uniform seedling progenies approach the uniformity of budded trees from the same parent. The study reported here was undertaken to provide some information on this question.

MATERIALS AND METHODS

At harvest time in 1945, 100 fruits were gathered from beneath each of about 10[1] seedling and 10 budded trees from the same parent, namely, F–2, F–9, F–99, L–2, and L–9. The F–2 and F–9 trees had been planted in 1930 on the grounds of the Florida Agricultural Experiment Station at Gainesville. The others had been planted in 1941 in test orchards in the vicinity of Bogalusa, Louisiana. In addition, similar fruit samples were taken from 10 trees of each of two seedling progenies, the A–27, in which the individual trees varied widely in type and productivity, and the L–47, in which the trees were relatively uniform.The trees were planted in the spring of 1941, near Folsom, Louisiana, but no clones propagated from the respective parent trees were available for comparison.

After the moisture content of the fruits had been brought to equilibrium with the vapor pressure of a saturated solution of calcium chloride at about 75 degrees F, the average weight per fruit, the average weight per kernel, the percentage of kernel in the whole fruit, percentage oil in the kernel and percentage of oil in the whole fruit were determined for each sample. The variation in these fruit characteris-

[1]As is indicated in the tables, a smaller number of trees of L–2 were available and slightly more of F–2 and F–9. All seedling trees had been grown from open-pollinated seed of the same parent as the budded trees.

tics between individual trees was then studied. It was found that there was rather close agreement between the means for fruit weights, kernel weights, and the percentage of oil in the kernels and whole fruits from seedling and budded trees from the same parent. Hence, the variances for each characteristic can be compared directly, without the necessity of calculating standard deviations and coefficients of variability. Whether one variance significantly exceeds the other may be readily determined from a table of variance ratios (table of F values) in any standard text on statistical methods. The variances for the fruits from the seedling trees, which were generally larger, were divided in each case by the corresponding variances for budded trees and the resulting ratios (F) are given in the tables.

Results

It is noted (Table I) that in all characteristics considered except weight of kernel, the variances for the fruits from the seedling trees of F–2 exceeded those of the budded trees. However, the differences

TABLE I—Relative Variability of Fruits from Seedling and Budded Trees of the F–2* Tung Clone

Characteristic	Seedling		Budded		Variance Ratio (F)
	Mean	Variance	Mean	Variance	
Oil in kernel (per cent)	60.0	27.4576	57.0	11.8336	2.32
Kernel in whole fruit (per cent)	32.29	9.6721	32.26	3.7636	2.57
Oil in whole fruit (per cent)	18.4	3.8416	17.58	2.2500	1.71
Weight each fruit (grams)	26.08	19.1844	24.66	5.7600	3.33
Weight each kernel (grams)	2.10	0.0361	2.03	0.0484	—

*Twelve budded and 10 seedling trees.
F required at .05, 2.90; at .01, 4.63.

attained statistical significance at the .05 level only in the case of weight per fruit. The difference in variability between seedling and budded trees is much greater in the case of F–9 (Table II), where statistical significance at the .001 level was attained for percentage of oil in the kernel, weight of fruits, and weight of kernel. Statistical significance at or near the .05 level was attained for percentage of kernel and percentage of oil in the whole fruit.

In the case of L–2 (Table III) and L–9 (Table IV) the fruits from the seedlings are the more variable, but no differences attained statistical significance at the .001 level. The percentage of oil in the kernel

TABLE II—Relative Variability of Fruits from Seedling and Budded Trees of the F–9* Tung Clone

Characteristic	Seedling		Budded		Variance Ratio (F)
	Mean	Variance	Mean	Variance	
Oil in kernel (per cent)	58.7	24.0100	57.3	3.6481	6.58
Kernel in whole fruit (per cent)	30.6	8.8209	27.7	4.0401	2.18
Oil in whole fruit (per cent)	17.0	4.3264	15.0	1.2544	3.45
Weight each fruit (grams)	23.1	15.6816	22.9	1.7956	8.73
Weight each kernel (grams)	1.9	0.1681	1.7	0.0256	6.56

*Fourteen budded and 12 seedling trees.
F required at .05, 2.63; at .01, 4.02; at .001, 6.13.

TABLE III—RELATIVE VARIABILITY OF FRUITS FROM SEEDLING AND BUDDED TREES OF THE L-2* TUNG CLONE

Characteristic	Seedling		Budded		Variance Ratio (F)
	Mean	Variance	Mean	Variance	
Oil in kernel (per cent)	65.9	1.7500	65.5	2.5000	—
Kernel in whole fruit (per cent)	38.2	3.1883	39.8	0.4562	6.99
Oil in whole fruit (per cent)	24.3	1.7233	25.1	0.8300	2.08
Weight each fruit (grams)	27.6	11.5883	28.3	4.6275	2.50
Weight each kernel (grams)	4.1	0.1617	4.2	0.0387	4.17

*Nine budded and seven seedling trees.
F required at .05, 3.58; at .01, 6.37; at .001, 11.13.

TABLE IV—RELATIVE VARIABILITY OF FRUITS FROM SEEDLING AND BUDDED TREES OF THE L-9* TUNG CLONE

Characteristic	Seedling		Budded		Variance Ratio (F)
	Mean	Variance	Mean	Variance	
Oil in kernel (per cent)	63.7	4.0033	64.4	4.5956	—
Kernel in whole fruit (per cent)	29.8	10.6644	31.0	2.4611	4.33
Oil in whole fruit (per cent)	18.2	5.6800	19.5	2.4578	2.31
Weight each fruit (grams)	31.0	8.6189	31.4	4.8178	1.79
Weight each kernel (grams)	3.8	0.0422	3.8	0.0500	—

*Ten trees each, budded and seedling.
F required at .05, 3.18; at .01, 5.35; at .001, 9.20.

was found more uniform in the seedlings of both L–2 and L–9 than in the budded trees; and in weight per fruit and in percentage of oil in the whole fruit, the variances for the seedlings exceeded those of the budded trees by differences too small to be statistically significant at the .05 level.

Fruits from seedling trees of F–99 were found to be more variable than those from budded trees, but both were remarkably uniform (Table V). It may be noted that the fruits of some clones are more variable than others. For example, fruits of F–99 were significantly more uniform than those of F–2 in respect to all characteristics studied.

It is worth while to note that the seedling trees of F–99 produced fruits that, although more variable than those of the clone F–99, compared favorably with fruits of most of the other clones studied.

The data in Table VI show that fruits of seedling trees of A–27 are considerably more variable than those of L–47. This is of interest

TABLE V—RELATIVE VARIABILITY OF FRUITS FROM SEEDLING AND BUDDED TREES OF THE F-99* TUNG CLONE

Characteristic	Seedling		Budded		Variance Ratio (F)
	Mean	Variance	Mean	Variance	
Oil in kernel (per cent)	65.7	0.7022	68.5	0.6844	1.03
Kernel in whole fruit (per cent)	40.2	1.0711	39.0	0.3711	2.88
Oil in whole fruit (per cent)	25.3	0.6433	25.6	0.3633	1.77
Weight each fruit (grams)	24.7	5.3256	25.1	1.0733	4.96
Weight each kernel (grams)	3.4	0.0755	3.4	0.0155	4.86

*Ten trees each, budded and seedling.
F required at .05, 3.18; at .01, 5.35.

TABLE VI—RELATIVE VARIABILITY OF FRUITS FROM SEEDLING TREES OF TWO TUNG CLONES, A–27 AND L–47

Characteristic	A-27*		L-47*		Variance Ratio (F)
	Mean	Variance	Mean	Variance	
Oil in kernel (per cent)	63.4	21.8900	65.5	0.7933	27.59
Kernel in whole fruit (per cent)	27.8	11.5511	35.2	2.1378	5.40
Oil in whole fruit (per cent)	17.0	10.2378	22.2	1.2889	7.94
Weight each fruit (grams)	30.3	39.3444	31.8	19.7133	2.00
Weight each kernel (grams)	3.4	0.5678	4.1	0.2022	2.81

*Ten trees from each seed source.
F required at .05, 3.18; at .01, 5.35; at .001, 9.20.

since, as has been noted previously, the seedlings of L–47 are relatively uniform in tree characteristics and in productivity, while those of A–27 are exceedingly variable. In turn the variances for fruit characteristics of L–47 are rather consistently higher than the corresponding variances for fruits of F–99 seedlings although the difference attains statistical significance at the .05 level only in the case of weight per fruit. The fruits of L–47 seedlings were much more uniform as to percentage of oil in the kernel and in the whole fruit and in the percentage of kernel in the whole fruit, than fruits of seedling trees of F–2 or F–9. On the other hand, fruits of F–2 seedlings were much more uniform in weight of kernel than those from L–47 seedlings.

DISCUSSIONS AND CONCLUSIONS

It is evident that in this study the fruits from seedling trees were consistently more variable than those from budded trees originating from the same parent. Not one character studied was found to be significantly more variable in fruits from budded trees than in those from seedling trees from the same parent. Some differences were observed in variability of fruits from different clones. Variations among the fruits of a clone may be due to differences in rootstocks, in soils, and in other environmental effects associated with location, factors which may vary from tree to tree. Cross-pollination may affect oil content and other endosperm characteristics. In addition the variations may be due in part to inherent characteristics of the clone; thus certain clones characteristically produce one or more small fruits in each cluster, and the nuts of some clones tend to be better filled than those of others. Therefore, variation in weight of fruit, in kernel, in degree of filling, or in oil content will be reflected in successive samples of 100 fruits whether taken from the same tree or from different trees of the same clone.

Very striking differences in variability of fruits existed between seedling progenies from different individual parent trees. Angelo (1) has noted that, although most tung trees produce rather variable seedling progenies, trees grown from open-pollinated seed of certain individual parents are rather true to type. Some geneticists have suggested that those individual tung trees that produce uniform seedlings may be apogamous. The evidence presented here, showing various degrees of uniformity in the several characters of fruits of different

seedling progenies, and consistently greater variability in seedling than in budded trees from the same parent, supports the opinion that segregation and recombination of genes takes place among the seedlings of all parents. The variations between the seedlings of any given parent will then depend in large measure on the degree of homozygosity of the parent trees. If any large degree of cross-pollination takes place in the orchard, the trees that produce uniform seedling progenies must be homozygous for a considerable number of dominant genes. Otherwise it would be necessary to assume that for example, the seedling trees surrounding the parent F–99 tree in a commercial orchard at LaCrosse, Florida, all produce pollen carrying practically identical genes, a virtual impossibility. The data for characters studied, are essentially what would be expected on the basis that the uniformity of the fruits from the seedling trees depends to a large extent on the genetic constitution of the tree from which the seed was harvested.

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Peach Fruit Bud Hardiness as Affected by Blossom Thinning Treatments

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In connection with some peach fruit bud hardiness investigations during the winter of 1946–47 it was found that buds from trees which had been blossom thinned the previous spring were somewhat hardier, as indicated by bud survival at low temperatures, than buds from trees which had not been blossom thinned. The unusually low temperatures which occurred in New York State in the winter of 1947–48 made it possible to obtain additional evidence on this relationship under field conditions. Chandler (1) has reported that fruit buds on trees which were hand thinned the previous season suffered less injury during a cold winter than buds on unthinned trees. The present study, however, gave an opportunity to compare the earlier, more effective blossom thinning with conventional hand thinning, as well as with no thinning.

Materials and Methods

The cold hardiness determinations in 1946–47 were made by the controlled, direct-freezing method employing a small, deep-freeze cabinet which has been modified for this work. The freezing compartment is equipped with a tank containing anti-freeze solution in which the tubes of twig samples are placed, and an agitator for maintaining uniform temperature throughout the solution. The characteristics and operation of the cabinet are similar to that described by Meader *et al* (3).

The peach trees from which the samples were collected for freezing tests in the winter of 1946–47 were in a block of Elberta and Veteran trees in Wayne County, New York. These trees had been included in a blossom thinning test in 1946 in which various materials and concentrations were compared for their thinning effect. The fruit set and yield data for the Elberta trees in this test have been reported previously by Southwick *et al* (4). The "check" or unsprayed trees were given a moderate hand-thinning by the grower in July after the set data were obtained.

Twig samples were collected February 8, 1947 from all 10 trees in the thinning treatments which were selected for hardiness comparison and composited for the freezing test. A sufficient number of twigs was included to give about 200 buds for each treatment. The samples were returned to Ithaca and immediately placed in the freezing cabinet. The temperature of the solution was dropped gradually (about 2 degrees F an hour) until the desired sub-zero temperature was reached. The solution was maintained at the desired temperature for an hour, then the samples were removed and the buds subsequently sectioned to determine survival.

The Elberta trees for which bud survival data were obtained following the low temperatures of January and February, 1948, were located in Orange County, New York. A blossom thinning test was conducted in this orchard in 1947. The fruit set and yield data have

been reported by Southwick *et al* (5). The data on bud survival and bud set were obtained April 1, 1948. Samples of from 200 to 250 buds were examined from each treatment.

Results and Discussion

The data on peach fruit bud survival following the artificial freezing tests are presented in Table I. The data for both temperatures to which the buds were subjected in the freezing chamber indicate that the buds on those trees which had been blossom thinned by dinitro compounds were hardier than buds on those trees which were not blossom thinned but were subsequently hand thinned.

TABLE I—Effect of Blossom Thinning on the Survival of Artificially Frozen Fruit Buds of Two Peach Varieties

Blossom Thinning Treatment 1946	No. Trees	Fruit Set (Per Cent) Jul 2, 1946	Average Yield (Bu/Tree)	Per Cent Fruit Buds* Alive After Exposure to:	
				−6 Degrees F	−8 Degrees F
			Elberta		
DN No. 1 May 13 ½ lb/100 gal	10	15.8	2.3	52.0	10.0
Check	10	45.6	3 1	20.5	4.4
			Veteran		
Elgetol May 14 1½ pt/100 gal	10	32.8	2.6	60.9	11.2
Check	10	58.0	2.6	41.5	7.1

*Samples collected and frozen February 8, 1947.

The difference in bud survival between the blossom thinned and hand thinned treatments is greater with Elberta than with Veteran. This is in apparent agreement with the degree of thinning which was accomplished with the two varieties. The Elberta were thinned to a greater extent by ½ pound DN No. 1 than were the Veteran with 1½ pints Elgetol per 100 gallons as indicated by the fruit set records.

The data on fruit bud survival for Elberta in the Orange County orchard are presented in Table II. The lowest temperature for the winter in the area where this orchard is located occurred on January 21 and was about −16 degrees F. The thinning accomplished by the two dinitro treatments was quite similar as indicated by the fruit set records which are presented in the table. The fruit bud survival for the trees which received these two treatments was also similar and it

TABLE II—Effect of Blossom Thinning on the Survival of Elberta Fruit Buds Frozen Under Orchard Conditions

Blossom Thinning Treatment May 9, 1947	No. Trees	Fruit Set (Per Cent) Jul 8, 1947	Average Yield (Bu/Tree)	Per Cent Fruit Buds Alive Apr 1, 1948	Average Fruit Bud Set	No. Live Buds Per Foot Apr 1, 1948
Elgetol 1 pt/100 gal	12	13.5	3.0	88.5	18.7	16.5
DN No. 1 ½ lb/100 gal	9	16.9	3.2	87.5	18.4	16.1
Check	5	35.5	3.4	67.9	10.5	7.1

was appreciably higher than the bud survival on the unthinned trees.

In addition to obtaining data on bud survival, the fruit bud development or bud set was determined for the trees in these plots. These data are presented in Table II. It was found that there were nearly twice as many fruit buds per foot of twig growth on the chemically thinned trees, as well as a greater length growth of the individual twigs. This effect of chemical thinning has been previously reported by Hoffman and Van Doren (2). When this increased bud set is related to the higher per cent of bud survival and expressed as number of live buds per foot of twig growth as done in Table II, the advantage of the thinned trees is apparent.

These results indicate that effective blossom thinning of peach trees which otherwise would set excessively increases the hardiness which the fruit buds on those trees may attain during the following winter. The early thinning, in addition to improving size and quality of the current crop and encouraging early growth, also favors the subsequent hardiness of the buds.

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Cold Injury to Dormant Buds of Two Tung Varieties and Its Effect on Yields

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The tung tree (*Aleurites fordi* Hemsl.) is subject to the same types of cold injury as have been reported for other deciduous trees (1, 3). Fernholz and Potter (2, 3) have reported inherent differences in cold resistance of budded and seedling tung trees and that these differences depend largely on the particular clone and the parentage of seedlings being compared. Freezing temperatures that injure the buds and blossoms after trees have begun growth in late winter or early spring is a very important factor in crop reduction. In 8 out of 26 years in the Gainesville district, from 1923 to 1948 inclusive, the tung crop has been reduced in varying degree from this cause.

Although crop reduction is caused most frequently by freezing temperatures which kill the blossoms after growth has started in late winter or early spring, this type of injury may occur in the fall or early winter before the trees have hardened sufficiently to withstand severe cold or while the trees are dormant. Low temperatures of mid-November, 1940, almost completely destroyed the 1941 crop by killing terminal buds and in many instances branches back into the 2- and 3-year-old wood. The fall and early winter months of 1946–47 were unusually warm, followed by one of the coldest Februaries on record. Though tung trees were dormant at the time low temperatures were experienced in late January and February, 1947, bud injury occurred.

A block of budded trees and seedling progeny of two tung varieties, Florida and F–9, were planted on the Experiment Station's minor Farm at Gainesville, in 1930. An examination, following the freeze in February, 1947, disclosed that there was some bud injury to the trees in this block. Bud counts were made April 17, when the trees were in full bloom, to determine the extent of the damage. The term "buds injured" includes dead terminal buds which made no growth and those so severely injured that their potential ability to produce fruit was impaired. However, only 68 of 7,527 buds examined were dead.

The data given in Table I show that the budded trees and seedling progeny of the variety F–9 had a greater per cent of buds injured than similar trees of the Florida variety and that these differences have high statistical significance. Also, F–9 seedling progeny had much less injury than budded trees of the same variety.

The average yield per tree for five years is used as an index to the normal ability to bear of the budded trees and seedling progeny of Florida and F–9 varieties under the conditions of this experiment (Table I). Analysis of the data shows that there is no significant difference in the ability to yield of the seedling progeny of Florida and F–9 varieties for the five years used. However, in 1947 the difference in average yield between these two groups of trees is highly significant and F–9, which had the greater per cent of its buds injured, also had the lower yield (Table I). The average yield for five years of F–9

TABLE I—PER CENT OF DORMANT BUDS INJURED BY COLD IN 1947 AND ITS EFFECT ON YIELDS OF SEEDLING PROGENY AND BUDDED TREES OF TWO TUNG VARIETIES

Variety or Seedling Progeny	Average Yield Per Tree		Per Cent Buds Injured
	Five Years* (Pounds)	1947 (Pounds)	
Florida-seedling	54.7	20.1	9.8
F-9-seedling	51.3	11.3	19.0
Florida-budded	36.4	17.9	8.6
F-9-budded	45.2	11.4	45.4
Least significant difference at 0.05	5.7	3.8	6.9
0.01	7.8	5.2	10.5

*The five years were 1940 to 1946, with the exception of 1941 and 1943 which were omitted because of crop reduction by cold injury.

budded is higher than Florida budded and this difference attains high statistical significance. In 1947, however, when F–9 budded had a higher per cent of buds injured, their yield is considerably below that of Florida budded and the difference is highly significant (Table I).

The data presented suggest that budded trees and seedling progeny of the Florida variety as a group came through the adverse winter conditions of 1946–47 better than similar trees of F–9 variety as a group, which is reflected in a lower per cent of buds injured and greater yields.

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More Than Thirty Peach Varieties Survived Minus Thirty-Two Degrees Fahrenheit[1]

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Low winter temperature is probably the greatest single limiting factor in the commercial production of peaches. The development of hardy commercial varieties for the colder peach growing sections of the United States is one of the most important objectives in fruit improvement work.

The information contained in this article is based upon observations made at the Station orchard under the conditions that existed during the winter of 1946–47. There seems to be no particular temperature at which killing of wood and buds is certain. Gardner, Bradford, and Hooker (4) and others have shown that no stated temperature can be assumed as fatal. Definite evidence, under experimental conditions, has shown that the critical temperature at which killing results is not a definite point for any species, variety or individual plant, but is the result of a complex of conditions. Thus, it is evident that any attempt to set definite temperatures as injurious or fatal without regard to other conditions is futile. However, it is agreed that fruit buds are generally more tender than other tissues.

Chandler (3) reported practically all peach trees killed in Wayne County, New York during the winter of 1917–18 when temperatures dropped to around minus 20 degrees F. The older trees and those bearing a heavy crop the previous year apparently were injured the most. Also as a result of a minimum temperature of minus 14 degrees F, Oskamp (5) estimated that at least 60 per cent of the bearing peach trees in Indiana were killed.

The rate of temperature fall is a very important feature in determining the amount of injury to winter buds and wood by a given low temperature according to Chandler (2).

Bradford (1) suggested that the ability of trees to withstand low temperatures depends in part on maturity of the buds and wood, the period at which the cold weather occurred, and the treatment any given tree or orchard may have received during the preceding summer and autumn.

During the spring months of 1943, 1944, 1945, and 1946, a total of 32 peach varieties were planted at the horticultural farm near Manhattan. The bulk of the plantings was made in the spring of 1943 with a few varieties being added each of the three following years. The varieties planted included Albru, Belle of Georgia, Candoka, Champion, Cumberland, Dixigem, Dixired, Early Triogem, Elberta, F. 44 (code name), Fisher, Halehaven, Hardee, Gage Elberta, July Elberta, Late Elberta, New Jersey 101, New Jersey 109, New Jersey 129, New Jersey 138, New Jersey 48836, Oriole, Raritan Rose, Redhaven, Rochester, Sullivan Early Elberta, Sun Glo, Sunhigh, Sun Gold, Valiant, Vedette, and White Hale. Most of the varieties set in 1943

[1]Contribution No. 220. Department of Horticulture.

produced a light crop of fruit in the summer of 1946. All of the trees made vigorous vegetative growth each of the growing seasons.

The summer of 1946 was unusually dry and hot, followed by a relatively early fall. Clean cultivation was practiced during the early summer with a cover crop of winter vetch being sown in mid-August.

The winter of 1946–47 was severe in Kansas with low temperatures being recorded late in the fall and continuing throughout the winter.

The temperature records were recorded by a Friez thermograph and by a self-recording maximum-minimum thermometer, both of which were enclosed in weather houses.

On Friday, December 27, a reading of 67 degrees F was observed, the highest temperature recorded for the period beginning December 6. During this period, the daily minimums ranged from freezing to 10 degrees F. From the high reading on December 27, the temperature dropped gradually until a reading of near minus 8 degrees F was reached on Monday, December 30. By referring to Fig. 1, it can be

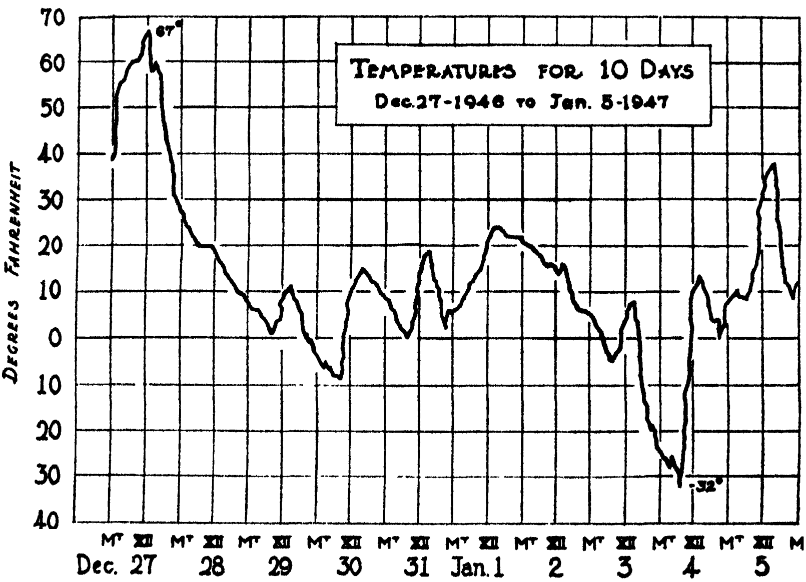

FIG. 1. Graph showing temperatures for 10 days, December 27, 1946 to January 5, 1947. Attention is called to the 48-hour period beginning at noon January 3, during which abrupt changes in temperatures were recorded.

seen that the temperatures fell to nearly zero twice on December 31 and below zero the morning of January 3. A high of 8 degrees F was reached on Friday, January 3. About 16 hours later, at nearly 6 a m, January 4, the temperature had dropped to minus 32 degrees F where it remained for about 1 hours. This represented a drop of 40 degrees F in 16 hours. By 3 p m the mercury had climbed to 13 degrees. Relatively cold weather followed this period for the next 2 months.

Investigations in the early spring showed that all fruit buds on all

varieties had been killed. A considerable number of 1-year-old twigs were killed. The sapwood of all trees investigated was discolored, ranging in color from dark walnut through various shades of brown. All bark seemed alive, though in places slightly discolored. The cambium layers of the older wood appeared uninjured.

In Table I observations made on May 1, 1947 are presented. Injury is indicated in the table by the terms light, medium and severe depending on the degree of severity of winter injury as evidenced by dead twigs and leaf buds, and discoloration of the sapwood.

As shown in Table I, on May 1 there was an observed difference between varieties in the amount of winter injury evident. Gage Elberta was the least damaged of all varieties and showed little winter injury. The variety Elberta also was in fairly good condition. All varieties

TABLE I—OBSERVATIONS MADE ON MAY 1, 1947 OF THE EXTENT OF WINTER INJURY TO PEACH VARIETIES

Variety	Winter Injury		
	Light	Medium	Severe
Albru		X	
Belle of Georgia			X
Candoka			X
Champion			X
Cumberland		X	
Dixigem		X	
Dixired		X	
Early Triogem		X	
Elberta	X		
F. 44 (Code name)		X	
Fisher		X	
Halehaven			X
Hardee		X	
Gage Elberta	XX		
July Elberta		X	
Late Elberta		X	
New Jersey 101			X
New Jersey 109		X	
New Jersey 129			X
New Jersey 138			X
New Jersey 48836			X
Oriole		X	
Raritan Rose		X	
Red Haven		X	
Rochester			X
Sullivan Early Elberta		X	
Sun Glo		X	
Sunhigh		X	
Sun Gold		X	
Valiant		X	
Vedette			X
White Hale		X	

showed the characteristic discoloration of the wood and partial killing of the twigs to some degree. Blackheart, as described by Gardner, Bradford, and Hooker (4), was in evidence in most trees examined. The growing conditions in the early part of the summer of 1947 were favorable with ample rainfall. Much of the growth made by the peach trees was from sprouts arising from dormant or latent buds on the branches, many of which elongated as much as three or four feet. The trees were not pruned except to remove dead wood.

The observations made re-emphasize that there is no particular temperature at which killing of wood and buds by low temperature is certain. All fruit buds were killed, but there is no way of determining

what temperatures were fatal. The injury to the leaf buds and the wood is variable as to the variety. It would seem probable that further damage to the twigs and leaf buds was prevented by the long exposure to low temperature which hardened the tissues. Although the temperature fell rapidly on January 3 and 4, the killing of the tissue due to rapid freezing might have been greater but for the protracted period of near zero weather immediately preceding this big drop in temperature.

It is possible that those trees most severely injured by the low temperatures may have had their longevity shortened. The mechanical strength of those branches showing severe blackheart type injury is likely to be reduced resulting in extensive splitting and breaking. When splitting and breakage do occur in the blackhearted wood, it is more susceptible to wood-decaying organisms than is uninjured sapwood or normal heartwood. Any such injured wood that is exposed to the air rots rapidly, thus the productivity and length of life of the injured tree is decreased.

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Some Artificial Freezing Tests of Peach Fruit Buds

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Fruit bud injury and killing by low temperatures is probably the most important single limiting factor in peach production in Illinois. These experiments were initiated with the object of developing a quick, reliable method of determining the relative hardiness of the fruit buds of peach varieties and seedlings throughout the season. This method will then be used in evaluating seedlings.

Equipment

A deep freeze unit similar to the one used by Meader *et al* (9) was adapted for freezing the fruit buds. The thermostat was sensitive to a three-degree change in temperature. The inside dimensions of the cold chamber were 32 inches by 20 inches by 29 inches. A wire rack 17 inches by 17 inches by 17 inches was made to place the twigs upon while they were in the chamber. A low temperature fan was directed downward and to the side so that the air was deflected from the bottom and sides. This successfully prevented stratification of the air within the chamber. A standard Weather Bureau thermometer was included with the twigs.

The above equipment was satisfactory but had to be carefully watched so that the temperature dropped at a uniform rate. It would be desirable, as equipment becomes available, to perfect the apparatus so that it would be more nearly automatic.

Methods

Vigorous representative terminal shoots were selected for freezing. At each freezing date at least 12 shoots were collected of each variety to be tested. The samples were not as homogenous as desired throughout the season because of the limited material to select from. Since one tree was all that was available of seedlings, the tree became depleted of its more vigorous shoots as the season advanced.

The twigs were held in an unheated building while being prepared for freezing. Two shoots of each variety were tied together, labeled, and then representative two-shoot samples of each variety were put together into larger bundles. They were then placed, with a thermometer, in the freezer which was adjusted to approximately the outside air temperature.

The temperature was then lowered from 3 to 4 degrees per hour during the first part of the freezing and then slowed down to 2 to 3 degrees per hour when killing temperatures were approached. This rate of temperature drop approximates the natural temperature drop for this vicinity when killing temperatures are experienced. Meader *et al* (9) used about the same rate of temperature fall in their experiments. Beginning at the point which was regarded as approaching critical, samples were removed at two-degree intervals in most of the tests. However, in some cases, samples were removed at one-degree intervals near the killing point of all the buds, and as much as four-degree intervals in the upper range of killing.

In preliminary tests it was found that the rate of thawing did not affect the amount of injury. This agrees with the work of Chandler (1), Meader *et al* (9) and others.

The fruit bud injury was determined by cutting the thawed buds transversely at the mid point with a razor blade.

Several varieties and hardy seedlings were selected for testing. Elberta and J. H. Hale were used as standards of comparison for the others. Elberta is known to be medium for fruit bud hardiness and J. H. Hale is tender in this respect.

These experiments covered the dormant period for three seasons. Table I includes the freezing dates and per cent injured of the varieties under test. Because of limited space only one graph (Fig. 1) showing the oncoming, fluctuations and decline of hardiness is included in this paper.

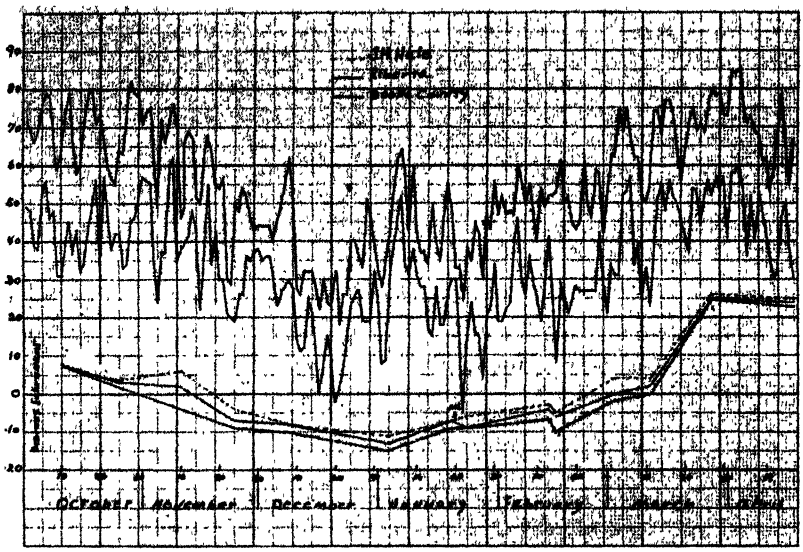

FIG. 1. Hardiness fluctuation of peach fruit buds as related to temperature (50 per cent injury — 1945–46).

SPECIAL PHASES OF HARDINESS

Hardiness of Peach Fruit Buds Before Leaf Fall:—It is interesting to note, in Fig. 1, that as early as October 10, 1945, when the trees still had all of their leaves, it required 8 degrees F to injure 50 per cent of the fruit buds of Elberta, J. H. Hale and Boone County. Referring to Table I, it will be seen that all but two of the varieties tested had approximately 50 per cent of their fruit buds injured at 8 degrees F. However, Prairie Dawn and Massasoit selfed had only 8 per cent damage at that temperature.

The degree of temperature endurance in the fruit buds before leaf

fall is extremely interesting in view of the fact that the bark of all varieties was badly injured at the same temperature. The bark on the terminal half of the twigs of all varieties was killed at 12 degrees and for the full length of the twigs of 3–7a–3, Elberta and K72. The buds that appeared to be normal at 8 and 10 degrees were severely injured at the point of attachment to the twig. The buds of most of the varieties

TABLE I—PERCENTAGES OF FRUIT BUD INJURY BY ARTIFICIAL FREEZING

Date	Temperature (Degrees F)	Elberta	J. H. Hale	Diamond King	Gage	Mass.	3–7a–3	Boone Co.	K111
				1044					
Jan 3	0	0	4	0	4	4	0	0	0
	−2	8	12	4	8	8	0	12	4
	−4	4	28	12	8	12	0	12	4
	−6	8	12	8	8	8	0	4	8
	−8	12	20	24	16	16	0	12	8
	−10	100	100	100	100	92	100	92	92
Jan 10	−4	0	0	0	0	0	0	0	0
	−6	0	4	8	0	0	0	0	0
	−8	8	12	16	0	4	4	4	8
	−9	8	20	16	12	8	4	12	4
	−10	32	32	44	16	4	4	12	8
	−11	32	28	64	16	4	4	8	4
	−12	64	40	60	76	16	12	20	20
	−13	100	100	100	100	92	92	92	92
	−14	100	100	100	100	100	100	100	100
Jan 21	−4	4	0	16	0	0	0	0	0
	−6	20	0	8	12	4	0	4	0
	−8	56	12	56	32	32	20	4	12
	−10	32	64	40	32	32	12	16	8
	−11	80	92	72	52	20	40	16	16
	−12	92	100	92	52	52	24	24	48
	−13	100	100	100	92	88	100	80	80
Feb 1	−4	72	80	68	36	12	20	24	20
	−6	96	100	88	68	60	48	56	40
	−8	100	100	100	80	72	88	100	48
	−9	100	100	100	88	88	80	100	72
	−10	100	100	100	100	92	96	100	92
	−11	100	100	100	100	92	100	100	100
Feb 14	−1	20	44	8	4	0	0	8	4
	−2	20	92	8	8	0	0	8	4
	−3	24	96	16	8	4	0	8	4
	−7	100	100	88	64	20	16	8	8
	−8	100	100	100	92	36	44	24	40
	−9	100	100	100	100	44	40	48	36
Feb 28	10	36	56	20	8	8	0	8	8
	8	40	60	32	12	36	4	8	4
	6	60	60	36	12	36	8	12	8
	4	60	84	48	16	40	8	16	20
	2	84	100	48	32	40	12	32	28
	0	100	100	64	52	64	24	44	40
	−1	100	100	88	68	68	24	44	48
	−2	100	100	100	76	72	48	60	68
	−3	100	100	100	92	92	80	84	88
Mar 7	7	40	48	24	16	12	4	0	4
	4	40	60	40	24	44	16	20	16
	2	52	76	40	32	24	0	24	16
	0	84	92	48	48	36	24	36	36
	−1	100	100	60	52	44	40	36	52
	−2	100	100	80	72	52	52	64	72
	−3	100	100	100	96	88	84	92	92
Mar 17	20	32	40	—	—	16	0	4	8
	18	46	44	—	—	24	4	0	8
	16	40	56	—	—	24	8	4	12
	14	52	60	—	—	12	8	8	12
	12	52	60	—	—	36	8	12	16
	11	60	84	—	—	16	12	12	8

TABLE I—*Continued*

Date	Temperature (Degrees F)	Elberta	Diamond King	Mass.	3-7a-3	Boone Co.	K111	K73	K74
				1944-45					
	−2	4	0	0	0	0	0	0	8
	−4	4	8	0	0	0	0	0	12
Nov 24	−6	76	68	52	40	12	36	40	84
	−9	100	100	60	64	44	76	84	100
	−10	100	100	80	88	76	84	72	100
	−12	100	100	100	100	100	100	100	100
	−4	0	0	0	0	0	0	0	4
Dec 1	−6	60	52	36	36	8	20	16	60
	−8	76	72	40	44	24	44	52	84
	−10	100	100	76	80	60	76	72	100
	−12	100	100	100	100	100	100	100	100
	−8	24	24	8	12	20	16	20	24
Dec 15	−10	24	24	12	12	20	12	20	36
	−12	40	48	12	12	24	28	24	52
	−14	68	100	48	44	28	44	44	76
	−16	100	100	100	100	100	100	100	100
	−7	12	16	12	8	0	4	8	16
Dec 31	−9	56	24	40	20	28	20	20	64
	−12	76	68	64	48	44	48	52	100
	−14	100	100	100	100	100	100	100	100
	−6	4	0	0	0	0	0	0	12
	−8	16	12	16	0	0	0	0	24
Jan 5	−11	44	20	32	16	4	12	16	62
	−12	84	80	80	52	64	68	64	100
	−13	100	100	100	100	100	100	100	100
	−6	4	0	0	0	0	0	0	—
Jan 21	−8	48	44	20	20	8	16	16	40
	−10	68	64	56	44	44	48	32	68
	−12	100	100	100	100	92	100	48	100
	−13	100	100	100	100	100	100	100	100
Feb 3	−6	8	0	0	0	0	0	0	0
	−8	20	16	0	0	0	0	4	0
	−10	24	28	8	8	0	0	12	12
	−12	24	28	8	8	0	0	12	12
	−13	24	28	24	8	0	0	12	24
	−8	48	44	60	32	36	16	10	76
Feb 11	−10	92	100	60	68	44	76	60	92
	−12	100	100	100	100	96	100	100	100
	−4	60	100	52	60	4	36	48	—
Feb 17	−6	96	—	80	68	60	60	60	48
	−8	100	—	100	100	92	100	92	100
	−9	100	—	100	100	100	100	100	100
	2	—	52	8	8	0	16	8	—
	0	38	100	24	24	24	32	24	28
Feb 27	−2	80	100	48	16	28	52	60	48
	−4	92	100	76	60	60	88	60	—
	−5	100	100	96	88	60	100	88	100
	−7	100	100	100	100	76	100	100	100
	6	28	—	—	8	16	8	18	40
	4	—	—	—	8	24	8	28	40
	2	24	—	—	4	20	16	36	32
Mar 9	0	72	—	—	8	28	48	28	88
	−2	96	—	—	52	56	68	76	88
	−4	100	—	—	72	80	88	40	100
	−5	100	—	—	92	92	100	100	100
	8	100	—	80	24	20	68	100	100
Mar 20	6	100	—	96	60	20	64	100	100
	4	100	—	100	44	24	96	100	100
	2	100	—	100	100	72	100	100	100
	0	100	—	100	100	80	100	100	100

TABLE I—*Continued*

Date	Temperature (Degrees F)	Elberta	Diamond King	Mass.	3-7a-3	Boone Co.	K111	K73	K74
1944-45—Concluded									
Mar 26	20	92	—	64	32	100	52	92	92
	18	88	—	64	56	100	92	76	100
	16	100	—	84	64	92	76	88	100
	14	100	—	100	56	96	60	88	92
	12	100	—	100	88	100	90	100	100
Apr 7	28	24	—	0	0	0	0	—	0
	27	20	—	0	0	0	0	—	0
	26	24	—	16	8	0	12	—	16
	25	64	—	96	16	12	36	—	96
	22	100	—	96	64	64	80	—	80
Apr 17	27	8	—	0	—	0	0	—	0
	26	12	—	0	—	0	0	—	12
	24	52	—	36	—	40	28	—	36
	22	100	—	100	—	92	100	—	100

Date	Temperature (Degrees F)	Elberta	J. H. Hale	South Haven	Kalamazoo	Eureka Hardy	Heath Cling	Hardy Berta	Vedette	Mass.	K73	K72	3-7a-3	Boone Co.
1945 46														
Oct 10	14	0	0	—	—	—	—	—	—	0	0	0	0	0
	12	36	40	—	—	—	—	—	—	8	0	36	28	36
	10	36	40	—	—	—	—	—	—	8	4	44	48	40
	8	44	52	—	—	—	—	—	—	8	8	52	48	44
Oct 26	15	24	32	—	—	—	—	—	—	0	0	24	12	0
	12	24	40	—	—	—	—	—	—	12	0	32	12	0
	8	32	32	—	—	—	—	—	—	12	16	36	28	0
	6	36	40	—	—	—	—	—	—	28	16	40	24	0
	4	36	52	—	—	—	—	—	—	28	24	40	24	0
Nov 10	12	0	0	—	—	—	—	—	—	0	0	0	0	0
	8	0	24	—	—	—	—	—	—	0	0	0	0	0
	6	32	64	—	—	—	—	—	—	0	0	40	0	0
	2	40	68	—	—	—	—	—	—	12	0	48	4	0
	0	80	64	—	—	—	—	—	—	20	0	48	24	4
Nov 24	−2	0	0	—	—	—	—	—	—	0	0	0	0	0
	−4	20	52	—	—	—	—	—	—	12	12	24	0	8
	−6	36	48	—	—	—	—	—	—	12	32	44	24	12
	−8	76	100	—	—	—	—	—	—	36	28	84	48	12
	−10	100	100	—	—	—	—	—	—	100	100	100	100	100
Dec 8	−4	0	0	—	—	—	—	—	—	0	0	0	0	0
	−6	20	40	—	—	—	—	—	—	0	0	40	0	0
	−8	40	52	—	—	—	—	—	—	12	12	56	8	8
	−10	76	88	—	—	—	—	—	—	52	52	88	48	44
	−12	100	100	—	—	—	—	—	—	92	88	100	88	88
Dec 23	−13	0	0	—	—	—	—	—	—	—	—	—	0	0
	−14	0	8	—	—	—	—	—	—	—	—	—	0	0
	−15	12	20	—	—	—	—	—	—	—	—	—	0	0
Jan 8	−10	0	32	—	—	—	—	—	—	—	0	20	0	0
	−12	28	84	—	—	—	—	—	—	—	20	48	0	16
	−14	100	100	—	—	—	—	—	—	—	40	100	24	16
	−16	100	100	—	—	—	—	—	—	—	100	100	100	100
Jan 20	−8	68	100	32	48	24	12	40	48	16	20	48	20	20
	−10	100	100	100	100	100	80	100	100	100	92	100	100	100
	−12	100	100	100	100	100	100	100	100	100	100	100	100	100

TABLE I—*Concluded*

Date	Temperature (Degrees F)	Elberta	J. H. Hale	South Haven	Kalamazoo	Eureak Hardy	Heath Cling	Hardy Berta	Vedette	Mass.	K73	K72	3–7a–3	Boone Co.
1945-46—Concluded														
Jan 23	−6	0	84	0	0	0	0	0	20	0	0	56	0	0
	−8	12	72	4	8	8	4	84	76	4	8	76	0	0
	−10	92	100	52	56	8	68	—	76	28	20	84	76	92
	−12	100	100	100	100	100	100	100	100	100	100	100	100	100
Feb 13	2	0	0	0	0	0	0	0	0	—	0	—	0	0
	0	0	20	0	0	0	0	0	0	—	0	—	0	0
	−2	16	32	0	4	0	0	0	12	—	0	—	0	0
	−4	60	80	16	28	16	4	28	60	—	8	—	4	0
	−6	84	100	68	36	28	8	60	68	—	8	—	16	8
	−8	100	100	100	100	100	100	100	100	—	100	—	100	100
Feb. 15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	−2	0	20	0	0	0	0	0	0	0	0	0	0	0
	−4	20	32	0	0	0	0	0	16	0	0	28	0	0
	−6	60	84	16	24	12	4	32	64	8	4	80	8	4
	−8	88	100	68	40	28	12	56	64	20	12	100	12	8
	−10	100	100	92	80	76	60	92	100	76	56	100	52	48
Mar 2	2	40	80	36	48	40	20	32	36	20	20	76	12	16
	0	56	88	68	72	72	44	68	76	48	28	84	20	28
	−2	92	100	84	80	84	76	88	92	76	48	100	44	52
	−4	100	100	96	100	92	88	96	100	92	96	100	88	92
	−5	100	100	100	100	100	100	100	100	100	100	100	100	100
Mar 11	4	36	84	28	40	32	20	28	36	24	20	76	16	20
	2	56	96	44	60	64	32	48	60	32	32	92	24	28
	0	64	100	68	84	92	60	76	88	56	52	100	48	48
	−2	100	100	92	96	100	84	92	100	88	80	100	72	76
	−4	100	100	100	100	100	100	100	100	92	92	100	88	88
	−5	100	100	100	100	100	100	100	100	100	100	100	100	100
Mar 27	28	32	28	16	32	20	4	20	32	0	0	32	0	0
	26	32	60	28	60	32	28	28	60	24	24	64	20	20
	24	92	100	92	100	96	96	96	100	100	100	100	92	88
	23	100	100	100	100	100	100	100	100	100	100	100	100	100
	22	100	100	100	100	100	100	100	100	100	100	100	100	100
Apr 17	28	12	16	8	—	—	0	0	—	—	0	16	0	0
	26	16	36	12	—	—	8	12	—	—	8	40	4	4
	24	56	92	52	—	—	24	36	—	—	24	100	16	12
	22	100	100	100	—	—	100	100	—	—	100	100	92	88

would eventually die because of the extensive bark damage at 12 degrees and they would all die at 8 degrees F. Neither the fruit buds nor the bark was injured at 14 degrees F. These results were corroborated in the 1946–47 experiment.

Hardiness at Leaf Fall:—Leaf fall had just been completed October 25, 1945 at the time of the second test of that year. During the period from October 10 to 26, as shown by Fig. 1, the fruit buds of Elberta gained 5 degrees in hardiness, those of J. H. Hale 4 degrees, and those of Boone County were not injured at all with a 4-degree lower temperature than was experienced on October 10. The other varieties gained in hardiness accordingly.

However, the bark at the tips of the twigs of Elberta and 3–7a–3 was injured at 15 degrees and for the terminal two-thirds of the twigs at 12 degrees. There was some injury at the base of the fruit buds on the terminal one-third of the twigs of Boone County at 12 degrees. The

bark of all varieties was so badly damaged at 4 degrees that the twigs would all die eventually. Perhaps the gain in hardiness would have been greater had the season not been so unseasonably warm.

Point of Greatest Hardiness:—Table I shows that the fruit buds of the varieties tested were at their maximum hardiness on January 10, 1944. December 15 was the date of greatest hardiness for the year 1944–45 and the buds were most hardy in early January in 1946.

These points of greatest hardiness seem to coincide very closely with the end of the rest period or shortly after its end. Hodgson (5), Howard (6), Knowlton and Dorsey (7), and Dorsey (4), report that the peach ends its rest period in early January or late December.

The Relationship of Temperature Fluctuations to Hardiness:—Stransbaugh (11), Mix (10), Knowlton and Dorsey (7), Dorsey (3), McMunn and Dorsey (8), and others have noted that fluctuations in temperature may cause a loss in hardiness of fruit buds which may result in severe injury by subsequent cold waves.

About January 15, 1944 the temperature started to rise gradually and reached its peak January 27, when it started a gradual decline. On February 1 the buds of most of the varieties had lost about 7 degrees in hardiness. The temperature continued to drop steadily and reached a low point of 1 degree above zero February 12. Most of the varieties regained 3 to 4 degrees in hardiness during this period. However, J. H. Hale lost 1 degree in hardiness. Perhaps this was caused by some unknown factor such as a weak twig. The temperature then started a gradual rise and stayed between 60 to 68 degrees F from February 20 to 25. As a result, the fruit buds lost 9 to 11 degrees in hardiness by February 28. After this period of warm weather, the temperature dropped again during the following week and all varieties regained some hardiness, ranging from ½ degree for Boone County to 3 degrees for J. H. Hale. From this point on, the temperature rose gradually and the hardiness lessened rapidly. The varieties retained their relative positions as to hardiness throughout this period.

During the dormant season of 1944–45, the peach fruit buds lost in hardiness three times because of periods of warmer weather. Twice, because of cold weather, the buds regained some hardiness. From January 12 to 25, 1945 the temperature was above normal and the fruit buds lost over 5 degrees in hardiness. The temperature then started to drop and reached a low of −4 degrees in about 8 days. Associated with this gradual temperature fall was a gain in hardiness of the fruit buds so that by the end of the cold spell they had more than regained their hardiness of early January.

During the winter of 1945–46, the fruit buds lost in hardiness four times because of temperature fluctuations, but regained some hardiness three times because of periods of cold weather. The last time, in each year, the hardiness decreased steadily until bloom.

Hardiness of the Peach Fruit Bud at Bloom:—Chandler (2) says that it is doubtful if a temperature of 24 to 25 degrees F will ever kill a large enough percentage of peach fruit buds to prevent a reasonably heavy bloom. These figures compare closely with those shown in Table I for some varieties during the winters of 1944–45 and 1945–46. How-

ever, for varieties such as J. H. Hale, K72, and others, 26 degrees would be a safer temperature. Although the hardiness differential was not so great at this time as during the winter, the varieties tended to keep their relative positions as to hardiness. Table I shows that 25 degrees killed approximately 50 per cent of the bloom of Elberta in 1945, while Boone County had the same amount of injury at 22 dedegrees. At 22 degrees all of Elberta's fruit buds were killed compared to 64 per cent for Boone County and K116 and intermediate amounts for other varieties.

The Hardiness Differential Between Varieties:—The difference in hardiness between peach varieties is not as consistent as could be desired. The difference varies greatly throughout the year and from year to year, depending upon environmental factors. However, the relative position as to hardiness is maintained fairly consistently.

Because of the relatively narrow difference between the most and least hardy varieties, there will be occasional years when the temperature will drop so low that the hardiness differential will be nullified, but at other times the more hardy varieties, such as Prairie Dawn, will come through with a crop while most other varieties will fail. The season of 1946 illustrates the importance of this small hardiness difference. On January 23 the temperature registered —8 degrees in the orchard. The buds of all varieties appeared to be only slightly injured (5 to 20 per cent). However, there must have been some injury to the ovules because the fruit of all the varieties, except Prairie Dawn, dropped before the June drop. Prairie Dawn, although growing in a low unfavorable spot, matured a full crop.

Summary

It was found that the fruit buds were definitely more hardy than the bark while the leaves were still on the trees in early October and there was very little gain in hardiness at leaf fall.

The point of greatest hardiness was reached by the fruit buds after the rest period was broken, or near its end.

The killing point of peach fruit buds fluctuates directly with the temperature changes during the winter months. The freezing tests made in this study show that the killing point of the fruit buds may rise as much as 11 degrees after a warm period, and that it may fall as much as 5 to 6 degrees after a cold spell.

The hardiness differential between varieties narrows down at bloom. The critical range for peach blossoms was found to be 24 to 26 degrees F. The more tender varieties were severely injured at the upper limit; Elberta, intermediate; and the more hardy varieties were killed at 24 degrees F. Some years, depending upon environmental factors, the limits may be slightly lower (23 to 25 degrees) than those given above.

At shuck fall the fruit was of about the same degree of hardiness as at bloom. However, some varieties showed slightly more hardiness at this stage.

The varieties consistently maintained their relative positions as to hardiness throughout the season and from year to year. However, the hardiness differential between varieties was not constant.

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The Nature of Giant Apple Sports and Their Use in Breeding

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ABSTRACT

This material has been published in full in the *Journal of Heredity*.

A COLLECTION of apple sports at the Graham Branch Experiment Station at Grand Rapids, Michigan, bearing "giant" fruits was examined in 1947 to see if any would be useful in breeding and to obtain information on possible tetraploid characteristics. Nine were giant forms of known diploid varieties; two were of known triploid varieties; and one was of unknown relationship. One only, the Ontario, had large pollen grains of the tetraploid type; the others were presumably chimeras having the third histogenic layer tetraploid. The trees producing giant fruits were characteristically very spreading, with wide-angled branching. The trees of the giant form of McIntosh, at least, were dwarfed. The giant fruits were flattened and 49 to 110 per cent larger than comparable normal ones. The flavor of giant McIntosh, Baldwin, Northern Spy, Jonathan, Steele Red, and 210–A (Bismarck type) was fully as good as of the normal types. The giant McIntosh trees for four crops gave a smaller yield than comparable normal trees.

It was concluded that the search for giant sports should be extended to find those with 4x second histogenic layers so that they could be used as tetraploids in breeding. A method such as the one suggested by Dermen may be used to obtain fully 4x trees from those having a 4x condition in the third layer only. The possible advantages of giant sports are that 4x and 6x sports of the varieties may be self-fertile, which would allow selfing and would make unnecessary the provision for cross-pollination in orchard plantings; that breeding on the 4x level may result in higher percentages of desirable seedlings; and that triploid, tetraploid, and hexaploid seedlings may be obtained at will, from which selections could be made freely.

The Effect of Severity of Pruning on the Performance of Young Elberta Peach Trees[1]

By Aubrey D. Hibbard, *University of Missouri, Columbia, Mo.*

Pruning, one of the oldest arts, is probably the last orchard operation to be put on a scientific basis. The application of scientific knowledge has resulted in improved practices in fertilization, soil management and moisture conservation. Through their intelligent use the grower is able to control the growth of the trees. The development of better materials and methods for pest control likewise permits a closer regulation of the functional leaf area of the tree. The mechanization of fruit production has also made possible many changes in cultural methods which were not practicable with the equipment previously available.

The value of pruning in training the young peach tree is generally recognized. Most peach growers are aware of the fact that pruning has a dwarfing effect which in turn reduces the production of fruit. Experience has shown that it is necessary to prune the peach tree more severely than any other orchard tree in order to secure profitable crops. Before the adoption of improved cultural practices, such as nitrogen fertilization, severe pruning was the only method known by which satisfactory growth for fruit bud development could be maintained.

Talbert (6) in Missouri and Greve (3) in Delaware made comparisons with young apple trees of pruning against no pruning. They showed that pruning delays the age of coming into bearing and also lowers the production during the early life of the orchard. McHatton (4) is of the opinion that Georgia peach growers should change the methods followed in pruning and larger trees should be developed. The relationship between pruning and nitrogen fertilization has been pointed out by Dorsey and McMunn (2). Lightly pruned young peach trees have been found by Savage and Cowart (5) to have larger and more extensive root systems as well as tops than the more heavily pruned trees.

During recent years there has been a gradual change towards lighter pruning of the peach. This is especially true in the recommendations appearing in the literature. Some growers have gone beyond these suggestions and have devised systems of light pruning of their own.

The objective of this study was to re-evaluate the present peach pruning methods recommended for Missouri conditions in relation to recent developments in improved cultural practices and mechanical fruit growing equipment.

The trees selected for this experiment were 2-year-old Elbertas set 24 feet apart on a square plan. They had received uniform pruning for both seasons. A good set of scaffold limbs had been developed during

[1]Contribution from the Department of Horticulture, Missouri Agricultural Experiment Station Journal Series No. 1093.

this training period. The three types of pruning described below were given to a block of 120 uniform trees. The treatments were applied in a design which allowed forty trees to receive each treatment. By this arrangement the treatments were replicated eight times in plots of five trees each.

Treatments

Moderate Pruning:—This is the type of pruning recommended in the more recent literature and is followed more or less by the better growers in most commercial districts. The terminal growth is headed back annually for a distance equal to about one-third of the new growth, and approximately one-third to one-half of the side shoots are thinned out.

Light Pruning:—This is essentially the "long" method (1) followed by some growers in certain districts. There is no heading back of the terminal branches. All cutting is confined to the removal of side growth and thinning out unwanted branches. This system resulted in the removal of only about 70 per cent as much wood as from the moderate treatment.

Corrective Pruning:—In this system only a minimum amount of pruning is given. The cutting is confined to the removal of interfering branches, those growing across the center of the tree or extremely vigorous shoots which tend to form new scaffold limbs. There is no thinning of the tops or cutting back of terminal growth. During the last few years only dead wood has had to be removed. Under this system the amount of wood removed has been less than one-third of that taken out under the moderate treatment.

Equal amounts of labor were required to perform the moderate and light types of pruning. The corrective method required only about one-fifth as much time since most of the work could be done by standing on the ground.

The cumulative totals by years for wood removed in pruning are shown in Fig. 1. It will be noted that the light and moderate systems required the removal of twice and three times as much wood as the corrective pruning.

The trees in these plots were given uniform culture. The soil was managed through a system of summer cultivation and annual legume cover crops. Nitrogen fertilizer was applied annually at the rate of ½ pound of a 20 per cent carrier for each year of growth. The crop was thinned uniformly and props to support the limbs have never been used.

The pruning was done each year during the latter part of February at which time weight of wood removed was recorded. Annual records were made of trunk growth and total weight of fruit harvested. Observations were also taken on the size and quality of the crop. At the end of the tenth growing season the trees were measured for height and spread. A record was also made of the large pruning cuts over 1½ inches in diameter which were unhealed at the time. New shoot growth was measured at the end of the ninth and tenth growing seasons.

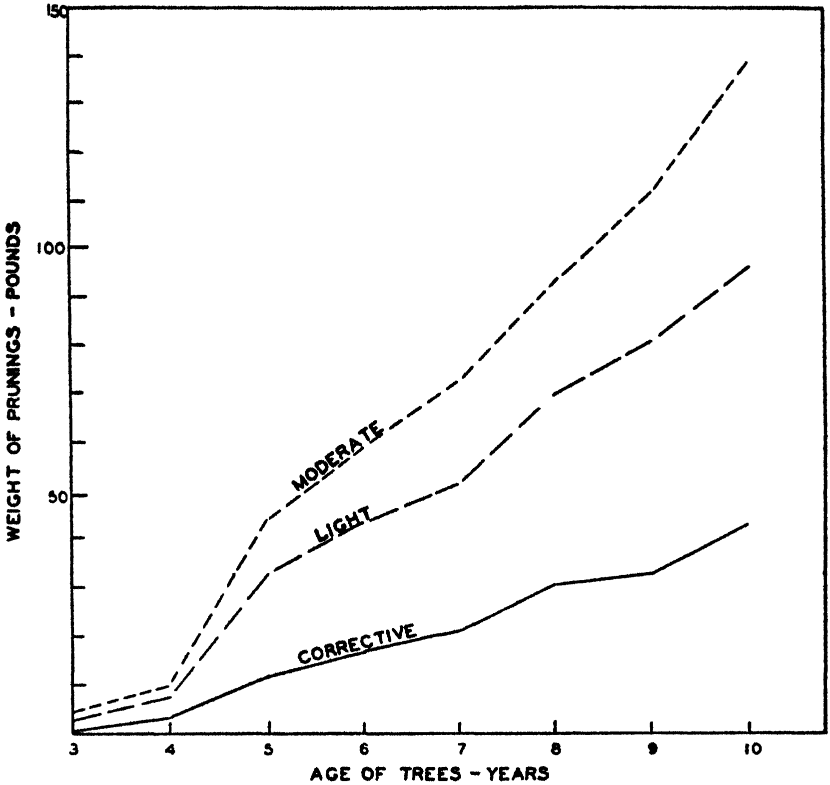

FIG. 1. Cumulative totals by years of wood removed from young peach trees by following three different systems of pruning.

RESULTS

The different degrees of pruning did not affect trunk growth to any significant extent (see Fig. 2). The other growth measurements show that the trees given light and corrective types of pruning were only 1 foot higher than those headed back annually. This difference was not apparent at harvest time since these trees tended to carry their fruit near to the ground. The branches appeared to be more flexible. Those not headed back averaged about 2 feet greater in spread. This is the great objection to the long systems of pruning since the wide spreading branches when loaded with fruit interfere with travel through the orchard. It is interesting to note that it has been necessary to make a greater number of large pruning cuts on the trees given the most severe type of pruning. This has been largely a result of breakage. The short, inflexible limbs of the moderately pruned trees have not been able to carry their crop as well as the more flexible branches. The trees with the thinning out or light type of pruning have suffered more breakage than those receiving only the corrective treatment. At the present time after 10 years of growth the trees receiving only

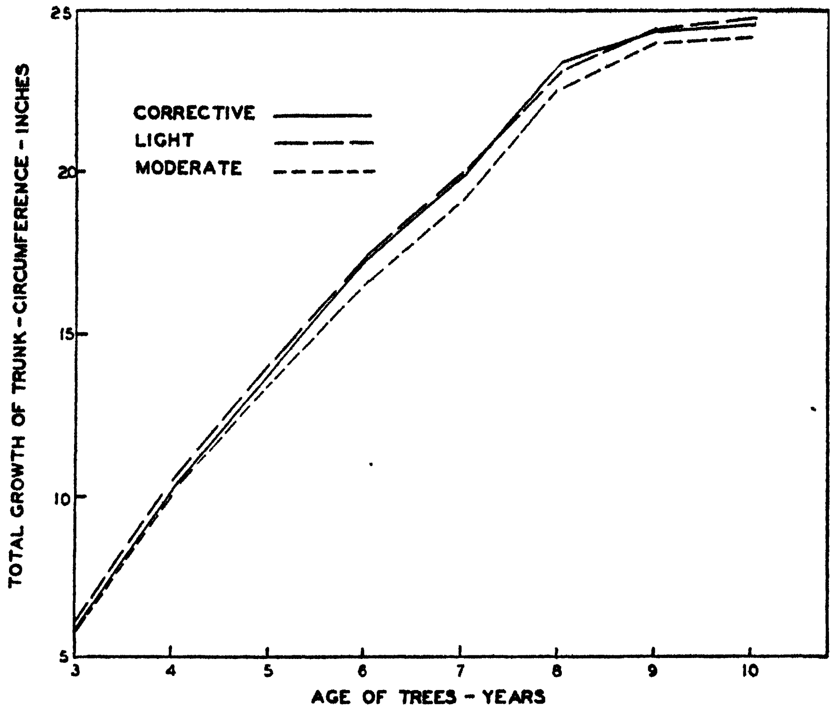

FIG. 2. Total trunk growth response of young Elberta trees from three systems of pruning.

corrective cutting are in better physical condition. Many of the large wounds near the main stem will probably never heal during the life of the orchard. Twig growth was not measured until the end of the ninth season. The measurements for the last two seasons are similar. The trees cut most heavily made the greatest average length of new growth. The average length of twig growth was 4.8 inches for the moderately pruned trees, 2.9 for the light, and 2.6 for the corrective. An average growth of 2 to 3 inches is usually considered to be too little for maximum production. This amount was sufficient, however, to set more than enough fruit for a full crop in 1947. In fact, these trees required considerable thinning.

The true value of any orchard practice is told in the yield and quality of fruit harvested (see Fig. 3). Six crops were secured during the 7 years of this study. There was a partial crop during the fifth season, but yield data were not recorded. During every one of the six crop years the trees receiving light or corrective pruning outyielded the moderate treatment. Those given the lightest treatment or corrective pruning only were the most productive. Their total production for the period of the experiment has accumulated to an increase of 24 per cent. The yearly increases varied from 16 to 41 per cent. There was no measurable difference in quality of the fruit from the different treat-

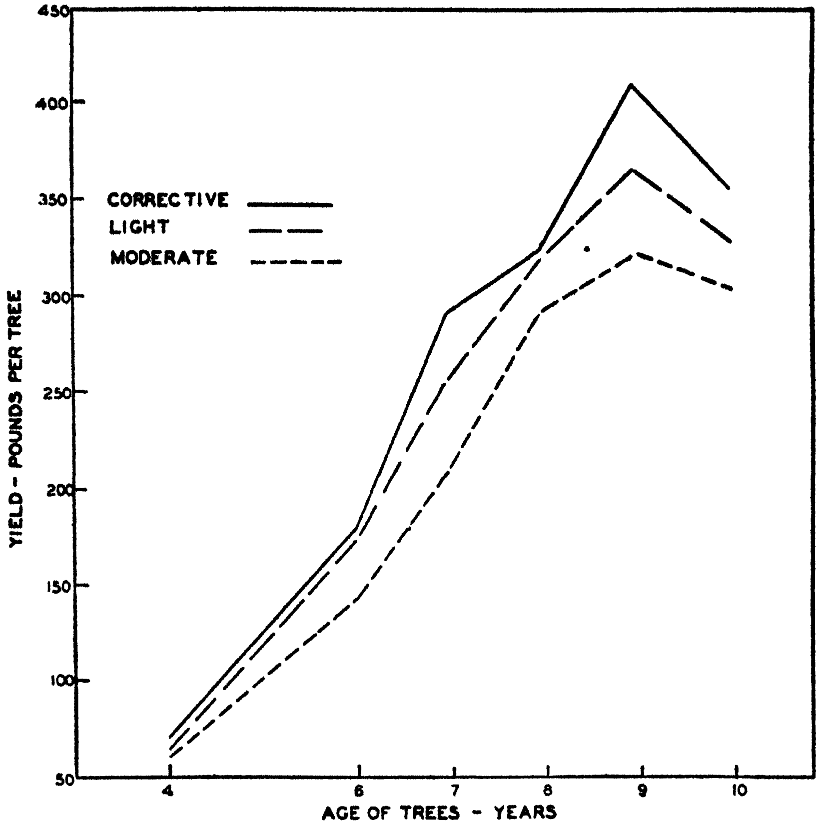

FIG. 3. Yearly yields of fruit from peach trees receiving corrective, light and moderate pruning.

ments. Disease and insect injury counts at harvest time indicated that spraying was equally effective on all treatments. The men who worked on these trees claimed that there was no difference in the amount of time required to thin the fruit. The pickers experienced no great difficulty in harvesting the crop from the lightly pruned trees.

SUMMARY

The corrective system has been most desirable so far under the conditions existing in this orchard. While the cost of pruning was less, the yields have been substantially greater for the six crop years. The thinning out system or light pruning apparently offers no advantages over the corrective system. The long barren limbs which develop under this practice seem to be more subject to breakage. The heavy breakage and loss of scaffold limbs under the moderate system seems to refute some of the strongest arguments for this system.

The chief disadvantage to maintaining trees under the corrective system in this orchard is that they occupy almost the entire orchard

space. With modern orchard machinery it is practicable to grow trees with a wider spread and branches nearer to the ground.

Since the differences in size of the trees under the various systems of pruning is not very great, this would suggest that the more heavily pruned trees have made wood and shoot growth at the expense of fruit production.

The results secured here indicate that the trend towards lighter pruning of peach trees is a sound practice, especially when combined with modern methods of culture.

A general recommendation for the corrective system of pruning must await further study under different conditions.

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Further Scion and Stock Combinations with Spy 227[1]

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SHAW and Southwick (2) reported in 1944 that certain varieties and strains of apple were lethal when budded on Spy 227, a clonal rootstock which was obtained from an open-pollinated seedling of Northern Spy. Of particular interest was the performance of two strains of McIntosh which were designated as McIntosh G and McIntosh R. These strains cannot be distinguished by vegetative or fruits characters; yet when budded on Spy 227 strain G made normal growth and developed into vigorous trees, while strain R made weak growth and by the second year the trees died. Tukey and Brase (4) report a similar performance with two other McIntosh strains. Yerkes and Aldrich (5) found strains of Winesap which were lethal to Spy 227 and some which grew normally.

Since Shaw and Southwick's (3) second report, various stock and scion combinations have been tried with Spy 227 to determine the nature of the trouble. This paper is a report concerning these combinations.

MATERIAL AND METHODS

In August of 1944 several combinations of stocks and scions were budded. They were (I) 25 Spy 227 budded to McIntosh G and R on the same stock, (II) 25 Spy 227 budded to McIntosh R, (III) 25 Spy 227 budded to Blaxtayman, (IV) 55 Spy 227-2 (an open-pollinated seedling of Spy 227) budded to Spy 227, (V) 70 Spy 227-12 (an open-pollinated seedling of Spy 227) budded to Spy 227, and (VI) six buds of McIntosh G set in a McIntosh R tree.

During the 1945 season the stock and scion combinations were given differential treatments. Combination I was treated as follows: (a) on four trees the McIntosh R buds were not allowed to grow, (b) on five trees the McIntosh R buds were allowed to make 4 to 6 inches of growth and then kept suppressed at this height, and (c) on nine trees both R and G buds were allowed to develop normally. Combination II had the following treatments: (a) on five trees McIntosh R buds were removed, (b) on five trees McIntosh R buds were allowed to make 4 to 6 inches of growth and were then kept suppressed at this height, (c) on five trees the McIntosh R buds were suppressed later in the season, and (d) on five trees McIntosh R buds were allowed to develop normally. Combination III was treated the same as II except Blaxtayman buds were used. Combination IV was rebudded to 10 McIntosh R, 10 Blaxtayman, 10 Staymared, 11 Delicious, and 10 Golden Delicious leaving 8 to 10 inches of Spy 227 interstock. Combination V was rebudded to 12 McIntosh R, 10 Blaxtayman, 10 Staymared, 11 Delicious, and 10 Golden Delicious leaving 8 to 10 inches of Spy 227 interstock. Fifteen buds of McIntosh G

[1]Contribution No. 659 of the Massachusetts Agricultural Experiment Station. The author is pleased to acknowledge the guidance and assistance of Dr. J. K. Shaw, Emeritus Professor of Pomology, who initiated this study.

which had been growing for a season in a McIntosh R tree (combination VI) were set in Spy 227 stock along with 15 McIntosh R buds from the same tree.

Scion combinations with Spy 227 which were budded in 1946 consisted of 10 McIntosh G buds from the McIntosh R tree, 10 buds from the McIntosh R tree which were sheared from the stock in November 1946, and 10 buds each the following varieties: Northern Spy, Red Spy, Foster Gravenstein, Whitcomb Gravenstein, Mead Gravenstein, Kendall, Milton, Early McIntosh, Macoun, Rhode Island Greening, Baldwin, and Galbraith Baldwin, a red bud-sport.

RESULTS

The trees of combination I (McIntosh G and R together on Spy 227) made normal growth during the 1945 season irrespective of their differential treatments, but by September of 1946 all were dead. The congenial McIntosh G strain failed to suppress the action of the lethal McIntosh R strain. Even preventing or suppressing the growth of R buds failed to stop their lethal effect. The toxic principle causing death is apparently not dependent on the development of any material in the leaf tissue of the lethal strain.

Trees of combination II where McIntosh R buds were used alone made fair growth during 1945. In 1946 all died somewhat before the trees in combination I. Complete or partial suppression of the growth of R buds again failed to prevent their lethal action. This condition is similar to that reported by Gardner, Marth, and Magness (1) with Rome Beauty on Spy 227.

Combination III had the same treatment as II except Blaxtayman was the lethal variety. The trees all died the same as when McIntosh R was the lethal variety, but they did not die as quickly. This was to be expected, as the lethal action of Blaxtayman on Spy 227 was found by Shaw and Southwick (3) to require two seasons before actual death of the trees occurred.

The results of combinations IV and V are shown in Tables I and II. Trees of the lethal strains and varieties budded on Spy 227 interstock with Spy 227–12 roots made better growth during the 1946 season than those on Spy 227 interstock and Spy 227–2 roots. With the exception of Blaxtayman practically all the trees on Spy 227–2 roots were dead at the end of the 1946 season. The fact that Blaxtayman does not die as quickly on Spy 227 roots probably accounts for its failure to succumb at this time. Trees on Spy 227–12 roots had fewer casualties at the end of the 1946 season and even where the top

TABLE I—GROWTH OF VARIETIES AND STRAINS ON SPY 227–12 WHERE SPY 227 WAS USED AS AN INTERSTOCK (COMBINATION IV)

No. of Buds Set to Strain or Variety	No. and Condition of Trees First Year (1946)	No. and Condition of Trees and Stock, Second Year (1947)
12 McIntosh R	9 good, 3 stocks	5 alive, 4 dead, all stocks alive
10 Blaxtayman	8 good, 2 stocks	7 alive, 1 dead, all stocks alive
10 Staymared	10 good	9 alive, 1 dead, all stocks alive
11 Delicious	7 weak, 4 stocks	4 alive, 3 dead, all stocks alive
10 Golden Delicious	10 fair to good	8 alive, 2 dead, all stocks alive

TABLE II—GROWTH OF VARIETIES AND STRAINS ON SPY 227–2 WHERE SPY 227 WAS USED AS AN INTERSTOCK (COMBINATION V).

No. of Buds Set to Strain or Variety	No. and Condition of Trees First Year (1946)	No. and Condition of Trees and Stock, Second Year (1947)
12 McIntosh R...........	5 dead, 6 weak, 1 stock	All dead; all stocks dead
8 Blaxtayman...........	8 fair to good	8 alive
8 Staymared............	4 dead, 2 fair, 2 weak	7 dead, 1 alive; 7 stocks dead
7 Delicious..............	3 dead, 2 fair, 2 weak	7 dead; all stocks dead
10 Golden Delicious.......	2 good, 2 fair, 4 weak, 2 dead	8 dead, 2 alive; 8 stocks dead

had died the stock was still alive. Wherever the budded trees on Spy 227–2 died, the stock died also. From these results it would appear that Spy 227–12 has a greater resistance to the toxic principle developed by the lethal combinations than Spy 227–2. Gardner, Marth, and Magness (1) found that, when Spy 227 was used as an intermediate root piece, lethal combinations died. Although these combinations are not the same, they are similar and indicate that Spy 227 may be able to transmit its toxic principle to a congenial rootstock.

During the early part of the summer of 1946, trees growing on Spy 227 (combination VII) which were propagated from buds of McIntosh G appeared to be making normal growth while trees of strain R were dying in typical fashion. The buds of McIntosh G were taken from a shoot which had been growing for one season on a McIntosh R tree. The buds for strain R were taken from the same McIntosh R tree. Later in the summer trees of strain G commenced to show typical symptoms of lethal combinations and by the following season the trees were all dead. This indicates that the topic principle of strain R was picked up by the heretofore resistant strain G. The transmission of the toxic principle of strain R was repeated in the 1946 budding (combination VIII). It would appear from the evidence at hand that the topic principle is a virus. If it is a virus it is of a most peculiar nature in that it only manifests itself when two comparable factors are brought together. At the present time there is no evidence that this virus has a vector and apparently it can only be transmitted by transferring virus tissue into a healthy tree.

The results of the 1946 budding on Spy 227 are shown in Table III.

TABLE III—1946 BUDDING ON SPY 227 (COMBINATION VIII)

No. of Buds Set to Strain or Variety	No. and Condition of Trees (October, 1947)
10 McIntosh G from McIntosh R tree	4 trees, weak growth, premature defoliation
10 McIntosh R buds sheared November, 1946	All stock dead
10 Northern Spy	7 vigorous trees, foliage shows no signs of premature fall
10 Red Spy	6 weak trees, premature defoliation
10 Foster Gravenstein	6 trees, weak growth, premature defoliation
10 Whitcomb Gravenstein	5 trees, weak growth, premature defoliation
10 Mead Gravenstein	10 trees, vigorous, but premature defoliation
10 Kendall	7 trees, vigorous, no premature defoliation
10 Milton	9 trees, vigorous, no premature defoliation
10 Early McIntosh	9 trees, vigorous, no premature defoliation
10 Macoun	9 trees, vigorous, no premature defoliation
10 Rhode Island Greening	6 trees, medium growth, premature defoliation
10 Baldwin	9 trees, medium to weak, premature defoliation
10 Galbraith Baldwin	5 trees, weak, premature defoliation

It is interesting to note that when the dormant McIntosh R buds were sheared from the Spy *227* stock in the fall all of the stocks died the following summer. This gives further evidence that the toxic principle does not depend on the development of leaf tissue in the lethal variety and also lends support to the virus theory.

It is not safe to say at the present time whether the different strains and varieties budded on Spy *227* in 1946 are lethal or not, but if they follow the usual pattern, Red Spy, Foster Gravenstein, Whitcomb Gravenstein, Mead Gravenstein, Rhode Island Greening, Baldwin, and Galbraith Baldwin will be lethal. Kendall, Milton, Early McIntosh, Macoun and Northern Spy will not be lethal.

Summary

Various stock and scion combinations of Spy *227* were made to determine the nature of the lethal principle which causes certain varieties and strains to die when propagated on Spy *227* rootstock.

It was demonstrated that the toxic principle could be transmitted from a lethal strain to a congenial strain, which would indicate that the trouble was of a virus nature.

It was also shown that the toxic principle causing death where lethal strains are involved is not due to any material manufactured in the leaves.

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Peach Variety Incompatibilities on Seedlings of a Yunnan Understock

By John T. Bregger, *Clemson, S. C.*

Several types of partial incompatibility have been observed in the realm of tree fruits when vegetatively propagated. These are usually found in closely related species and commonly result in dwarfing.

Dwarfing effects of peach stocks are quite rare and seldom reported. In most cases it has been assumed that the cause of dwarfing lies with the bud variety, especially when it exists to the same degree on a variety of understocks. The dwarf growing habit of the J. H. Hale variety bears out this contention.

Several investigators have worked with Shalil and Yunnan stocks in an attempt to produce peach trees resistant to the root-knot nematode. Where poor growth of peach trees has been noted on such understocks, it was presumably attributed to nematode infection rather than to incompatibility between stock and bud variety.

In the growing season of 1946, the author's attention was drawn to the unusually poor growth of about 45 Redhaven "June buds" on Yunnan P. I. 55886 seedling understocks,[1] in comparison with adjoining "June buds" of Sullivan Early Elberta on the same stock. Not only were these Redhaven trees decidedly dwarfed, but the foliage was yellow, spotted and somewhat crinkled. In contrast to these Redhavens, the Sullivan Ey. Elberta trees were of normal size and carried dark green foliage. Nearby trees of both varieties on Lovell understocks appeared normal in all respects.

Following these limited observations, a more comprehensive test of varieties was carried out in 1947. Due to the limited number of available seedlings of the same Yunnan P. I. 55886 seed source, not more than five trees of a variety were budded. A total of 19 varieties were used giving a rather wide coverage of the commercial peach variety list. A few buds died after insertion, but enough survived to give rather definite if not significant differences in their compatibility with the Yunnan understock. The results of this experiment are summarized in Table I.

Discussion

In analyzing the data as presented, it appears that out of the 19 peach varieties tested, only seven (Dixigem, Elberta, Fair Beauty, Goldeneast, Halegold, Rio Oso Gem and Sullivan Early Elberta) had a completely compatible relationship with the seedlings of this particular Yunnan selection. Among these, the Rio Oso Gem, chosen because of its abnormally dwarf habit of growth on ordinary understocks, showed an apparently normal stock-scion relationship. In contrast to the growth of Rio Oso Gem, a self-fertile strain of J. H. Hale was more dwarfed on the Yunnan seedlings than on Lovell seedling understocks.

[1]From seed of white cling Yunnan 55886 grown at United States Horticultural Field Station, Fort Valley, Georgia.

One hypothesis is advanced which might explain why some peach varieties are dwarfed by a certain understock while others are not. Apparently it is a type of incompatibility wherein the passage of

TABLE I—Growth and Reaction of Nineteen Peach Varieties on Yunnan P. I. 55886 Seedling Understocks

Variety	No. Buds Inserted	No. Buds Survived	Size of "June Buds" When Dug (Inches)	Remarks
Belle of Georgia	4	4	All 6-12	Very weak; yellow leaves
Burbank July Elberta	5	4	All 6-12	Weak; yellow leaves
Dixigem	5	3	All 24-36	Good vigor; green leaves
Dixired	5	4	2 6-12 2 12-18	Weak; yellow leaves
Elberta	5	5	All 24-36	Good vigor; green leaves
Early Red Fre	5	4	All 12-18	Yellow leaves
Fair Beauty	5	4	3 24-36 1 18-24	Good vigor; green leaves
Fairhaven	5	1	12-18	Yellow leaves
Fertile J. H. Hale	5	3	All 6-12	Stunted; yellow leaves
Goldeneast	5	3	All 24-36	Good vigor; green leaves
Golden Jubilee	5	4	2 6-12 2 12-18	Yellow leaves
Halegold	4	3	All 24-36	Good vigor; green leaves
Halehaven	3	2	All 6-12	Very weak; yellow leaves
Redhaven	5	4	1 6-12 3 12-18	Weak; yellow spotted leaves
Rio Oso Gem	4	4	All 12-24	Good caliper; green leaves
Southland	5	5	4 6-12 1 12-18	Very weak; yellow leaves
Sullivan Early Elberta	5	4	3 24-36 1 18-24	Good vigor; green leaves
Sunhigh	5	3	1 24-30 2 6-12	Weak; yellow leaves
Triogem	5	4	All 6 12	Very weak; yellow leaves

nitrates between the stock and scion is restricted, since leaf yellowing and spotting were generally associated with the dwarfed condition. Furthermore, there are probably certain genetic factors involved as evidenced by the Elberta group of varieties (including the Goldeneast, a seedling of Elberta) showing a consistently compatible relationship as compared to most if not all of the varieties of J. H. Hale — South Haven parentage.

Additional studies should be made to determine other factors involved in the stock-bud relationship. These should include further observations on the trees already propagated as well as additional buddings to ascertain what other varieties are dwarfed by this and other Yunnan stock selections.

Ascorbic Acid Content of 33 Peach Varieties in Relation to Genetic and Environmental Factors[1]

By QUENTIN ZIELINSKI, *Oregon Agricultural Experiment Station, Corvallis, Ore.*

SCHATZLEIN (5), Floyd and Fraps (1), Wittwer and Hibbard (6), and others have made a more or less comprehensive study of ascorbic acid content of the older peach varieties. Initial work in connection with the Oregon peach breeding program, which has as one of its objectives the nutritional values of these fruits, has made it possible to expand earlier determinations and evaluate certain modern commercial varieties and recent experiment station releases. The relationship of season of ripening and genetic constitution has been considered in enumerating data and discussion. Though these studies do little more than confirm and expand previous work, they do seem to merit recording and evaluation.

EXPERIMENTAL PROCEDURE

Preparation of samples for analysis followed the procedure of Loeffler and Ponting (3). Duplicate or triplicate 50-gram samples, consisting of pared, sliced sections from 12 fruits, were ground with 300 ml of 0.2 per cent oxalic acid solution for 3 minutes in a Waring blender. The resulting suspension was filtered and 5 ml aliquots were pipetted into 50 ml volume flasks and made to volume with sodium citrate-metaphosphoric acid buffer solution at pH 3.6. Final ascorbic acid was determined colorimetrically by the method of Morell (4) adapted for use with a Klett-Summerson photometer.

In order to obtain data on the influence of ripening period on ascorbic acid concentrations, samples of each variety were collected during three periods — early, mid-harvest, and late. The interval elapsing between samples was variable since varieties vary in length of season. Samples were selected to be uniformly near soft ripe. Fruits were chosen from the periphery of the tree in comparable light exposure.

RESULTS

The ascorbic acid contents of 33 peach varieties are shown in Tables I, II, and III. Each table is followed by a summarized analysis of variance for significance.

Table I lists seven varieties ripening more than 25 days before Elberta. The mean ascorbic acid content of the varieties analyzed

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The author expresses appreciation to Dr. Elmer Hansen, Associate Horticulturist, Oregon Agricultural Experiment Station, for his suggestions of methods, laboratory assistance and calculation of colorimetric values.

TABLE I—Ascorbic Acid (Vitamin C) Content of Peach Varieties Grown at Corvallis, Oregon in 1947 (Peach Varieties Ripening More Than 25 Days Before Elberta)

Variety	Parentage	Replication	Ascorbic Acid Per 100 Grams Fresh Fruit			
			First Harvest (Mg)	Mid Harvest (Mg)	Late Harvest (Mg)	Seasonal Mean (Mg)
Early Halehaven	Mutation of Halehaven	I II	7.09 6.84	7.85 7.85	5.32 7.85	7.13
Fisher	Mutation of Valiant	I II	2.28 2.28	2.53 2.02	2.28 2.53	2.32
Golden Jubilee	Elberta × Greensboro	I II	2.28 2.28	2.78 2.53	2.78 3.04	2.62
Oriole	Slappey × Admiral Dewey	I II	2.28 2.78	2.02 3.29	2.53 3.80	2.78
Raritan Rose	J. H. Hale × Cumberland	I II	0.76 1.01	2.02 1.77	2.53 2.02	1.69
Redhaven	Halehaven × Kalhaven	I II	1.52 1.52	4.81 5.06	6.84 3.29	3.84
Triogem	J. H. Hale × Marigold	I II	2.53 2.53	1.27 2.02	4 31 3.80	2.74
Mean						3.30

TABLE I—Data, Analysis of Variance

Sources of Variation	df	ss	Variance	Variance Ratio	
Variety	6	117.60	19.60	12.72	Very significant
Harvest time	2	8.24	4.12	2.67	Not significant
Experimental error	12	18.50	1.54	—	
Error of chemical determination	21	12.13	0.58	—	
Total	41	156.47	—	—	

Standard error of the difference between two variety means is 0.72.
A difference of 1.56 between two variety means is significant at 5 per cent level.

ranged from 1.69 to 7.13 with a seasonal mean of 3.30 milligrams per 100 grams of fresh fruit. In the analysis of variance there is no significant difference in harvest time. A highly significant difference exists in varietal means. Conspicuously high in ascorbic acid among early season varieties is Early Halehaven, having also the highest ascorbic acid content of any variety in this test.

Data listed in Table II record 19 varieties ripening less than 25 days before Elberta. The mean ascorbic acid content of such varieties ranged from 6.25 to 0.30 with a seasonal mean of 3.65 milligrams. It is to be noted that Early Charlotte ranked highest in this group while Improved Elberta gave the lowest value of all varieties in this test. Analysis of variance revealed very significant varietal differences with no significant differences in harvest time.

Data covering six late season varieties ripening after Elberta indicate a range from 2.19 to 6.67 milligrams of ascorbic acid with a seasonal mean value of 4.61. Varietal differences are less marked and

significant only at the 5 per cent level. Time of harvest was not significant.

Analysis of data indicates that under the prevailing conditions of this experiment, there were no significant differences when comparing early-season, mid-season, and late varieties by the *t* test.

1. Early-season versus mid-season (Table I versus Table II)
   The experimental errors of Tables I and II are not significantly

TABLE II—Ascorbic Acid (Vitamin C) Content of Peach Varieties Grown at Corvallis, Oregon in 1947 (Peach Varieties Ripening Less Than 25 Days Before Elberta)

Variety	Parentage	Replication	Ascorbic Acid Per 100 Grams Fresh Fruit: First Harvest (Mg)	Mid Harvest (Mg)	Late Harvest (Mg)	Seasonal Mean (Mg)
Early Charlotte	Open pollinated Early Crawford	I II	6.33 2.78	8.61 4.81	8.61 6.33	6.25
Eclipse	J. H. Hale × Marigold	I II	1 41 4 04	5.06 5.06	3.29 2.79	3.61
Goldeneast	Elberta × N. J. 38 E. G.	I II	6.84 6.08	7.09 5.82	5.32 5.32	6.08
Halehaven	J. H. Hale × Southaven	I II	4.81 5.53	5 06 5.32	6 08 6.59	5.57
Ideal	———	I II	4.81 1.41	4.05 2.78	5.82 5.82	4.12
Improved Elberta	———	I II	0 00 0.00	0 51 0.25	0.76 0.25	0.30
Improved Rochester	———	I II	4.31 4.81	5.32 4.81	5.82 6.33	5.23
Late Crawford	———	I II	4.31 4.31	1.41 4.05	1.41 3.80	3.22
Pacemaker	J. H Hale × Marigold	I II	2.78 1.41	3.04 2.78	2 53 3.29	2.64
Radiance	Belle × Greensboro	I II	4.31 4.31	4.31 4.31	2.53 2.53	3.72
Red Rose	Carmen × Slappey	I II	2.02 1.77	1.41 3.04	2.28 2.53	2.18
Slappey	———	I II	3.04 3.29	2.02 2.53	2.02 2.02	2.49
Southhaven	Mutation of St. John	I II	3.80 3.80	3.80 4.56	4.56 4.81	4.22
Summercrest	J. H. Hale × Cumberland	I II	1.27 1.77	2.53 2.53	2.28 3.04	2.23
Sunhigh	J. H. Hale × N. J. 40 C. S.	I II	4.31 3.80	4.05 3.80	4.56 4.56	4.18
Valiant	Open Pollinated Elberta	I II	4.31 4.81	3.80 4.81	5.06 5.06	4.64
Vedette	Open Pollinated Elberta	I II	2.02 2.02	2.28 2.78	3.54 3.54	2.70
Veteran	Vaughan × Stark's Early Elberta	I II	4.05 1.41	2.53 3.04	2.78 2.78	2.77
White Hale	J. H. Hale × Belle	I II	3.04 2.28	3.04 3.29	4.05 3.80	3.25
Mean............						3.65

TABLE II—DATA, ANALYSIS OF VARIANCE

Sources of Variation	df	ss	Variance	Variance Ratio	
Variety	18	242.79	13.49	11.44	Very significant
Harvest time	2	5.95	2.97	2.52	Not significant
Experimental error	36	42.44	1.18	—	
Error of chemical determination	57	43.13	0.76	—	
Total	113	334.31	—	—	

Standard error of the difference between two variety means is 0.63.
A difference of 1.27 between two variety means is significant at 5 per cent level.

different from each other. The pooled experimental error is 1.27 with 48 degrees of freedom.

$$t = \frac{3.65 - 3.30}{\sqrt{1.27\ (1/42 + 1/114)}} = 1.72$$

This shows that Table I does not differ from Table II.

2. Table I and II versus Table III.
   The pooled mean of 1 and 2 is 3.56 and the mean of Table III is 4.61.

$$t = \frac{4.61 - 3.56}{\sqrt{\frac{1.27}{156} + \frac{6.06}{6}}} = 1.04$$

The difference is not significant.

Discussion

A review of the limited literature available has indicated that vitamin C potency is related to seasonal and climatic conditions and it is generally conceived that sunlight intensity has a direct influence on the vitamin content. Strawberries (2) grown and ripened under reduced light intensity contained less ascorbic acid than those ripened on plants fully exposed to light. Since shading of the entire plants (2) resulted in a much greater reduction in ascorbic acid than did shading the berries only, this experiment was arranged to test the influence of total accumulated hours of sunshine expressed on a relative basis as reflected by the season of maturity and harvest dates.

It is apparent from the analysis of data that no significant differences exist between ascorbic acid content of early, mid-season, and late peach varieties in this test. Since differences between varieties were so highly significant, it is reasoned that genes governing the formation of vitamin C are of such potency that they mask the presence of environmental influences. This is clearly shown in the case of Early Halehaven. Ripening among the early season varieties, it gives a high value of 7.13 milligrams. Further, Early Halehaven differs in being significantly higher in ascorbic acid than its parent Halehaven which ripens 7 to 10 days later. The significance of this lends support to the view that several genes governing characters other than the visible one are involved in so-called simple mutations.

TABLE III—Ascorbic Acid (Vitamin C) Content of Peach Varieties Grown at Corvallis, Oregon in 1947 (Peach Varieties Ripening With or After Elberta)

Variety	Parentage	Replication	Ascorbic Acid Per 100 Grams Fresh Fruit			
			First Harvest (Mg)	Mid Harvest (Mg)	Late Harvest (Mg)	Seasonal Mean (Mg)
Afterglow	J. H. Hale × N. J. 27116	I II	6.33 6.08	7.34 6.84	6.84 6.59	6.67
Fay Elberta	———	I II	1.27 2.02	2.02 2.53	3.28 2.02	2.19
Fertile Hale	Mutation J. H. Hale	I II	3.28 3.28	2.02 2.02	3.28 3.28	2.86
J. H. Hale	Chance seedling	I II	1.76 0.56	0.51 0.26	8.10 8.87	3.34
Lovell	Chance seedling	I II	6.08 6.08	6.84 7.60	8.10 8.10	7.13
Shotz Late Hale	———	I II	4.81 4.81	5.82 5.32	6.08 5.82	5.44
Mean						4.63

TABLE III—Data, Analysis of Variance

Sources of Variation	df	ss	Variance	Variance Ratio	
Variety	5	130.97	26.19	4.33	Significance at 5 per cent
Harvest time	2	28.74	14.37	2.37	Not significant
Experimental error	10	60.56	6.06	—	
Error of chemical determination	18	2.89	0.16	—	
Total	35	223.16	——	—	

Standard error of the difference between two variety means is 1.42.
A difference of 3.17 between two variety means is significant at 5 per cent level.

The variety of J. H. Hale is worthy of note since it is so largely consumed in the fresh-fruit state. Table III, listing the analysis of this variety, shows a marked differential between first, mid-harvest and late harvest values. Why this spread should be so large is not understood. Certain varieties were placed in cold storage for temporary holding. Although there are no data on influence of storage on ascorbic acid in peaches, this may partially account for the observation.

Analysis of parentages compared with ascorbic acid content indicates that the variety J. H. Hale and its derivatives tend to give progenies with higher ascorbic acid content but this is not statistically significant. Too few varieties and lack of analysis of entire progenies make it impossible to generalize on the relative genetic effects of parental combinations.

In each of the three analysis of variance, the harvest time for a a variety shows no significant differences. However, the ascorbic acid content as can be noted from Tables I, II, and III fluctuated during the season and there exists an indication of a trend toward higher values for the last harvest. This appears to be especially true for the varieties Raritan Rose, Redhaven, Triogem, Vedette, J. H. Hale,

and Shotz Late Hale. A corresponding negative association appears in the case of Late Crawford, Radiance, Slappey, Veteran, and Fertile Hale. It has been noted by Hansen and Waldo (2) that with some varieties of blackberries there was a decrease in ascorbic acid content as the season advanced. In view of the very small experimental error, these data do not offer an explanation for the observed trends.

Summary

A study has been made as to the variability of ascorbic acid in 33 peach varieties grown in Oregon in 1947. The ascorbic acid content ranged in this study from 8.87 to 0.00 milligrams per 100 grams of fresh fruit.

In each of the three analysis of variance, within the limits here discussed, the harvest time shows no significant differences, while varieties show highly significant differences. Comparisons of early, mid-season, and late varieties indicate that these do not differ from each other.

Since highly significant differences occur between varieties and since variation in harvest time was not significant, it is concluded that the production of vitamin C is largely under genetic control and that the environmental factors studied in this report exhibit only a modifying influence.

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Some Effects of Harvesting Methods and Container Performance on Keeping Quality of Louisiana Peaches

By D. C. Alderman, *Louisiana Agricultural Experiment Station, Baton Rouge, La.*

The Louisiana peach industry with its considerable expansion during the past few years has developed many problems in harvesting and marketing. A heavy demand due in part to war conditions has thus far enabled growers to dispose of their crop locally and at a good price. As prices decline with decreased local demand due to returning normal conditions, more selling effort will be necessary if producers are to satisfactorily dispose of their future crops. This study was begun in 1946 in the interest of the Louisiana peach industry. Special emphasis has been placed on experimentation with harvesting methods and the relative efficiency of different types of containers.

The peach varieties used in the study were Golden Jubilee and Elberta and fruits of both varieties were picked as close to a tree-ripe condition as possible. The fruit and shed facilities were provided by the Bastrop Orchard Company at Bastrop, Louisiana. The work during the seasons of 1946 and 1947 dealt principally with the sources and amount of bruises occuring on the peaches in harvesting, packing and transporting operations. Harvesting studies included manner of picking and the method of moving the peaches from orchard to shed. The factors considered in measuring the relative efficiency of shipping containers were in connection with bruising, rate of cooling, durability, ease of handling and cost.

Bruising in Harvesting and Packing Operations

Source of Bruises:—The amount of bruises on the fruit delivered to market was less in 1947 than in 1946, and was probably due more to improved technique in harvesting and shed operations than anything else. The percentage of bruised fruits recorded at the different stages of handling for the period are shown in Fig. 1. Nine per cent of the peach bruises in 1947 and 14 per cent in 1946 developed while the fruit was still on the tree. From tree to shed the bruising increased to 36.5 and 39.0 per cent, respectively. Most of the increase for both years may be assigned to careless picking. The records for 1947 indicate that about two-thirds of the bruises were due to picking operations and one-third to natural causes. The more seriously injured peaches constituted about 20 per cent of the total bruised fruits entering the shed. This fruit was not shipped by producers but sold to local buyers at prices reduced as much as $1.75 to $2.75 a bushel. The peaches which were shipped brought to the growers $5.00 and over a bushel. Obviously, careless picking was costly to Louisiana peach producers.

Container Performance

Bruises:—One of the most important considerations in the selection of any container in which fresh peaches are to be shipped is its ability

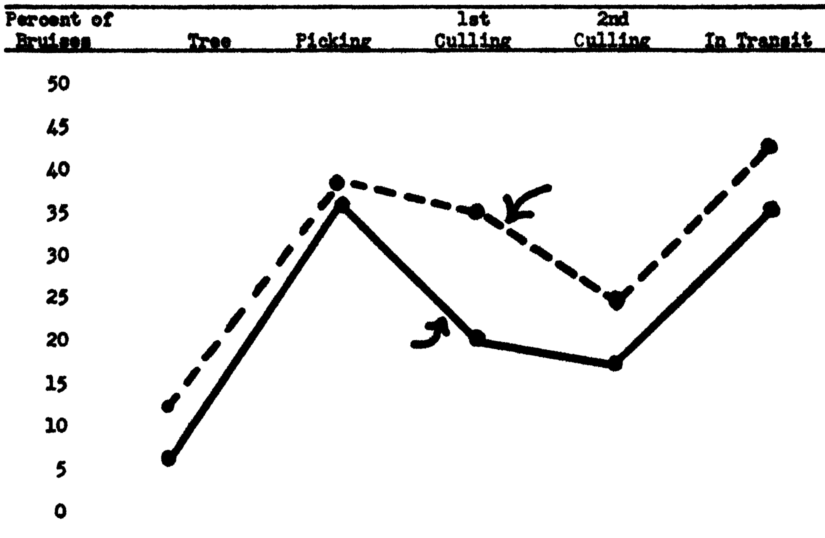

FIG. 1. Relative difference in amount of bruises in 1946 and 1947 incurred at various stages in harvesting and handling of Golden Jubilee peaches.

to prevent serious bruising in transit. Ten different types of containers were used in the 1947 studies: four bushel-type baskets comprising the nonventilated bushel, half bushel, the ventilated bushel and half bushel; Spartan and half Spartan wire bound boxes resembling sweet potato crates (see Fig. 2); the Los Angeles wooden tomato lug; a 30-pound fibreboard drum; and two cell-type paper board boxes; the 96-cell box and the Friday pack.[1] The nonventilated bushel basket, the conventional peach container of the East was used as a basis of comparison.

The effectiveness of the containers was determined by checking the number of bruises per peach in each box and converting into percentages as shown in Table I. It will be noted that the conventional bushel baskets contained fewer perfect peaches upon arrival at the terminal market than did any of the new types of boxes. Peaches packed in the ventilated bushel basket received 31.2 per cent bruising in transit as contrasted to 1.5 per cent bruising occurring on peaches

[1]The 96-cell box consisted of four layers of 24 cells each. The layers were separated by a flat cardboard sheet which rested on top of the cells. The Friday pack was simply a large paperboard box containing paper pulp layers into which moulded cups or depressions had been pressed in order to accommodate the fruit. Succeeding layers of fruit were prevented from resting on the lower layers by raised pyramids of paper pulp alternating with the cups. The 30-pound fiberboard drum, called the "Hat Box", packed three layers of peaches. This box was difficult to pack due primarily to the odd arrangement for separating one layer of fruit from the next. Notched cardboard squares fitted together to form a cross and four such crosses formed the supports for each succeeding layer. It required considerable dexterity to keep these crosses in place while packing and resulted in a good deal of lost motion.

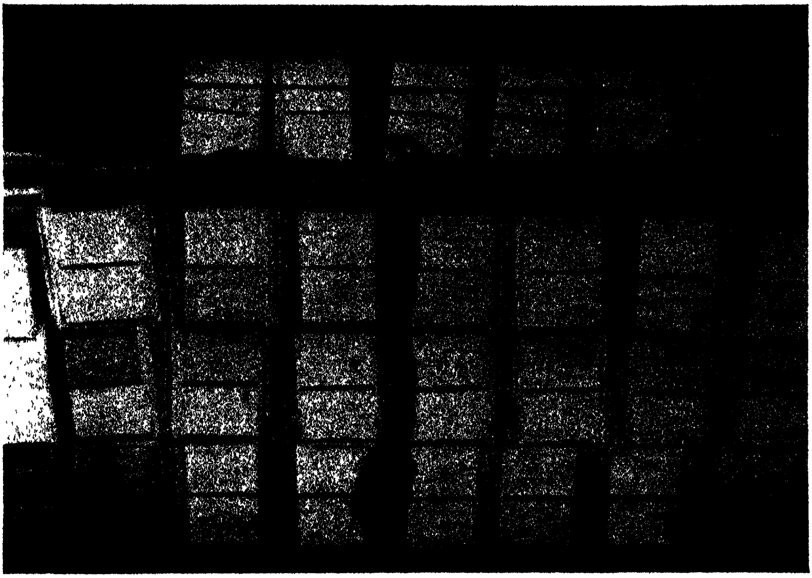

FIG. 2. Truck load upon arrival in Shreveport, one-half Spartan boxes.

packed in the tomato lug. It will be noted that peaches packed in the bushel type containers received considerably more bruises per fruit than those packed in other containers. Twenty-one per cent of the peaches in the ventilated bushel containers sustained two or more bruises. Among the other containers the Spartan box and Hat box contained a few peaches with two or more bruises. Not to be overlooked is the fact that 14.6 per cent of the peaches in the 96-cell box received bruises during transit. Many of these bruises were probably due to the fact that the peaches were a little too small for the cells. Perhaps more significant than comparisons of bruises among the various packages used was the relationship of the nonventilated bushel basket to the other containers. The differences in amount of bruising incurred during transit from shed to market between peaches in the nonventilated bushel and each of the other containers were measured by calculating Chi square for each comparison. These values along with the probabilities are shown in Table II.

Rate of Cooling:—Temperature as well as humidity is frequently very high during harvest season in northern Louisiana. Such conditions are ideal for the development and spread of brown rot and it is important that preventive measures be taken before the fruit is shipped. One very effective method is to reduce internal fruit temperature to at least 50 degrees F.

Containers of the different types mentioned were used in this experiment. Differences in the rate and manner of cooling of peaches packed in these containers were determined. The peaches used were all of U. S. No. 1 grade and ranged in size from 2 to 2¼ inches. Six

TABLE I—COMPARISON IN PER CENT OF AMOUNT OF BRUISING INCURRED DURING TRANSIT AMONG PEACHES PACKED IN DIFFERENT CONTAINERS FOR 1947

Type of Container		Bruises Per Peach								
		0	1	2	3	4	5	Soft	Rot	Total
Bushel basket non-ventilated	Shed	89.0	10.1	0.5	0.0	0.0	0.0	0.4	0.0	100.00
	Market	77.5	14.8	3.5	1.2	0.0	0.0	2.9	0.1	100.00
	Difference	11.5	4.7	3.0	1.2	0.0	0.0	2.5	0.1	——
Bushel basket ventilated	Shed	83.6	13.6	0.9	0.5	0.0	0.0	0.0	1.4	100.00
	Market	52.4	24.1	7.7	4.7	1.2	0.4	7.1	2.4	100.00
	Difference	31.2	10.5	6.8	4.2	1.2	0.4	7.1	1.0	——
½-Bushel basket non-ventilated	Shed	83.3	16.1	0.4	0.0	0.0	0.0	0.2	0.0	100.00
	Market	63.2	23.6	6.5	2.1	0.4	0.2	3.8	0.2	100.00
	Difference	20.1	7.5	6.1	2.1	0.4	0.2	3.6	0.2	——
½-Bushel ventilated	Shed	78.2	18.0	1.4	0.5	0.2	0.0	0.4	1.3	100.00
	Market	61.8	19.9	6.0	2.4	0.6	0.0	8.2	1.1	100.00
	Difference	16.4	1.9	4.6	1.9	0.4	0.0	7.8	0.2	——
Spartan box	Shed	92.5	7.5	0.0	0.0	0.0	0.0	0.0	0.0	100.00
	Market	89.5	5.0	1.1	0.5	0.0	0.2	3.2	0.6	100.00
	Difference	3.0	−2.5	1.1	0.5	0.0	0.2	3.2	0.6	——
One-half-Spartan box	Shed	92.6	7.1	0.0	0.3	0.0	0.0	0.0	0.0	100.00
	Market	89.8	5.9	2.2	0.0	0.0	0.0	1.5	0.6	100.00
	Difference	2.8	−1.2	2.2	−0.3	0.0	0.0	1.5	0.6	——
Hat box	Shed	81.4	18.6	0.0	0.0	0.0	0.0	0.0	0.0	100.00
	Market	78.4	15.7	3.9	0.0	0.0	0.0	1.0	1.0	100.00
	Difference	3.0	−2.9	3.9	0.0	0.0	0.0	1.0	1.0	——
96-cell box	Shed	92.7	7.3	0.0	0.0	0.0	0.0	0.0	0.0	100.00
	Market	76.0	21.9	0.0	0.0	0.0	0.0	2.1	0.0	100 00
	Difference	16.7	14.6	0.0	0.0	0.0	0.0	2.1	0.0	——
Tomato lug	Shed	95.4	4.6	0.0	0.0	0.0	0.0	0.0	0.0	100.00
	Market	94.0	5.3	0.0	0.0	0.0	0.0	0.7	0.0	100.00
	Difference	1.4	0.7	0.0	0.0	0.0	0.0	0.7	0.0	——

TABLE II—RELATIONSHIP OF STANDARD BUSHEL TO NINE OTHER CONTAINERS IN AMOUNT OF BRUISED PEACHES AS SHOWN BY CHI SQUARE

	X^2 Values								
	Ventilated Bushel	½ Non-Ventilated Bushel	½ Ventilated Bushel	½ Spartan Box	Spartan Box	"Hat Box"	Friday Pack	96-Cell Box	Tomato Lug
Non-ventilated bushel	−34.16	−6.57	−2.23	+6.56	+6.27	+6.32	+4.09	−2.39	+8.72
Probability	0.01	0.013	0.15	0.013	+ .012	0.012	0.045	0.15	0.01

−Comparison favorable to standard bushel.
+Comparison unfavorable to standard bushel.

peaches from the center of each container were selected for the purpose of recording internal fruit temperature under cold storage conditions. Records were kept on each of the tested fruits and readings were taken hourly for the first 4 hours, again at the end of 6 hours, and the final recording was made after 19 hours in storage. The temperature in the storage room averaged 43 degrees F during the day and approximately 37 degrees F at night. In analyzing the data, the six test-fruits from each container were considered as replications and an analysis of variance of temperature change in respect to the containers was determined. The F value for containers was 2.54 and

was significant at the 5 per cent level. Highly significant values of 52.7 and 3.33 were obtained for time in storage and the interaction between containers by time in storage. The mean loss in fruit temperature per hour per peach as packed in the different containers is shown in Table III. Attention is called to the average hourly loss

TABLE III—MEAN LOSS IN FRUIT TEMPERATURE IN DEGREES F PER HOUR PER PEACH AS PACKED IN EACH OF SEVEN CONTAINERS

Hours in Storage	Containers						
	Friday Pack	Hat Box	½ Bushel	Half Spartan	Bushel	Spartan Box	96-Cell
1	5.67	14.83	12.33	15.67	12.50	17.17	6.83
2	9.83	3.67	8.67	5.17	6.17	6.17	5.17
3	5.17	6.50	3.67	4.50	6.00	4.17	3.33
4	2.83	3.67	2.67	4.50	2.33	4.17	2.83
6	1.83	3.83	3.83	5.17	3.50	3.83	6.00
Average	5.07	6.50	6.23	7.00	5.10	7.10	4.65

(4.65 degrees F) of peaches packed in the 96-cell box, the Friday pack and the nonventilated bushel which was noticeably less than the average hourly loss for the other four containers. The highest average temperature losses per hour were 7.0 degrees F and 7.1 degrees F and occurred among peaches packed in the half and full Spartan boxes. These values were much greater than those obtained from peaches in the standard bushel, the 96-cell and the Friday pack.

It will be recalled from the above that a highly significant F value for the interaction of containers by the time in storage was obtained suggesting a measurable differential in the rate of cooling. Specifically

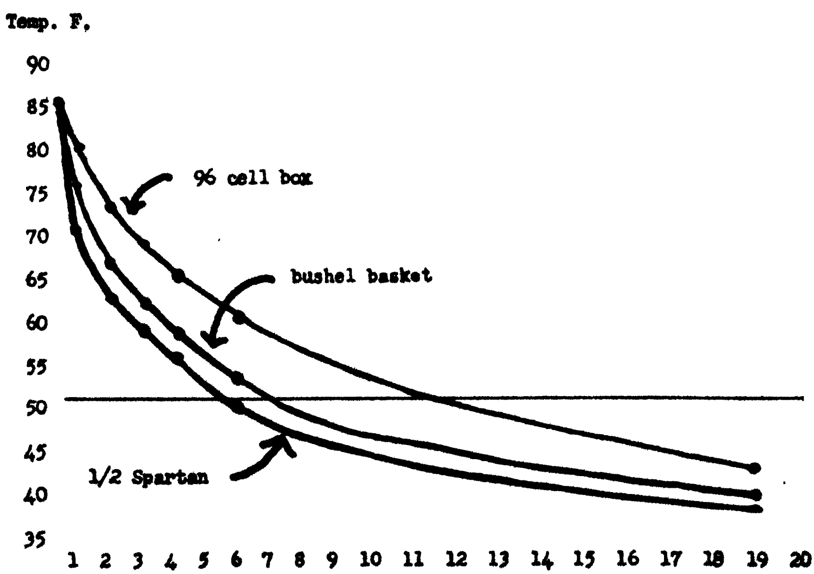

FIG. 3. Rate of cooling of peaches in three different containers as shown by internal fruit temperature.

the significant cross differences (5.23 degrees F at 5 per cent level) between the hours in the storage and the containers serve only to emphasize differences in rate of cooling among the containers. This is more clearly shown in Fig. 3 where temperature change of peaches packed in the various containers was plotted against time in cold storage. It would appear from this chart that the differential in rate of cooling among the containers was well established after 2 hours in cold storage. It is also interesting to note that peaches in the 96-cell box required 12 hours, or more than twice the time needed by the Spartan boxes, to reach 50 degrees F, a temperature below which the rate of respiration is low and internal breakdown of the peach is retarded. The removal of excessive fruit temperatures is of special importance to Louisiana growers who not only often harvest their peaches during hot and humid weather conditions, but expect, in the future, to deal with "tree ripe" fruit.

Effect of Precooling on Net Weight of Peaches:—The net weight of peaches as packed in the various containers was determined at the beginning of the cold storage period, again 19 hours later, and finally 8 days later. Changes in weight were calculated on the basis of 100 pounds to permit comparisons between the different containers and are presented in Table IV. There was a loss in weight in the first 19

TABLE IV—Calculated Weight Change in Pounds Per 100 Pounds of Peaches Packed in Different Containers After 19 Hours and After 8 Days in Cold Storage

Time in Storage	Containers						
	Friday Pack (Lbs)	Hat Box (Lbs)	½ Bushel (Lbs)	Half Spartan (Lbs.)	Bushel (Lbs)	Spartan (Lbs)	96-Cell (Lbs)
19 hours	−1.32	−1.46	−2.37	−1.82	−3.33	−1.75	+2.17
8 days	−3.70	−1.93	−0.93	−0.91	——	−1.31	−1.65
Total (19 hours and 8 days)	−5.02	−2.92	−4.30	−2.73	——	−3.06	+0.52

hours in six of the seven containers used which varied from 1.32 pounds to 3.33 per 100 pounds. The other container, the 96-cell box sustained a gain in net weight of over 2 pounds. Further weight loss after 19 hours and up to 8 days in storage continued at a very much reduced rate. In fact, the total average drop in weight from 19 hours to 8 days was only a little more than the total average loss during this first 19 hour period. This does not include the bushel basket, which had to be discarded when the test bushel was removed and sold. The loss of weight for each container at the end of 8 days was not sufficient to cause noticeable shrivelling, but many of the fruits presented a somewhat rubbery feeling upon handling.

Quality of Stored Peaches:—Louisiana peaches have been and probably will continue to be competitors for the early market and there is no particular advantage to be gained by storing them any great length of time. Under the conditions of this experiment it was possible to make only general observations as to the effect of containers on the quality of stored peaches. The Friday Pack, The "Hat

Box", the ½ bushel basket, the half Spartan box, the bushel basket, the Spartan box, and the 96-cell box were used. The experiment was conducted on both Golden Jubilee and Elberta. The cold storage period extended 14 days for Golden Jubilee and 12 days for Elberta. Indications were that the type of containers had little effect on the keeping ability of peaches in cold storage. Off flavors had developed in all stored material and shrivelled fruit was found in about the same amount in all containers at the end of the storage period.

General Consideration:—In order to simplify total evaluation of the containers seven judgment factors, each worth 10 points, were applied to the various carriers with the summarized score presented in Table V. The factors used in evaluating the containers were: amount of bruising in transit, rate of cooling, keeping ability, strength of container, general appearance of container when packed, ease of handling and cost. According to the total scores the tomato lug and the Spartan boxes gave the best overall performance, while the Friday pack and "Hat box" scored the lowest. The low score of the "Hat box" is no doubt due to its poor handling and packing qualities. The bushel containers did not attain superiority largely because they failed to prevent excessive bruising of the fruit while in transit. The tomato lug scored well on all points, but at the present time neither the growers nor the wholesalers are prepared to pack or accept shipments of peaches in these boxes. However, the performance of this container indicates favorable potentialities and it is possible that with some improvement it could come into general use. The results obtained in 1946 and 1947 serve to point out several defects in the bushel type baskets as containers for moving tree-ripe peaches to market. It is a negative approach to the problems but in view of the low rating accorded the bushel type of baskets on bruises, it is suggested that the ½ Spartan box and the 96-cell box be given preference.

TABLE V—CONTAINER PREFORMANCE ON THE BASIS OF JUDGMENT SCORES OF SEVEN ESSENTIAL FACTORS

Containers	Bruises in Transit	Rate of Cooling	Keeping Ability	Container Strength	Container Appearance	Ease of Handling	Container Cost	Total (Possible 70 Points)
Tomato lug	9	10	8	10	6	10	8	61
½ Spartan	8	10	8	9	9	10	7	59
1 Spartan	8	10	7	7	8	9	8	57
Standard bushel	5	7	7	9	7	8	10	53
½ Ventilated bushel	4	9	8	8	8	7	8	52
½ Standard bushel	3	8	9	8	8	7	8	51
96-cell	9	4	9	5	10	4	9	50
Ventilated bushel	1	8	6	6	8	8	10	47
Hat box	8	8	7	10	5	2	6	46
Friday pack	6	5	8	4	6	5	7	41

SUMMARY

A total of 10 different containers were used in this study to evaluate their efficiency as carriers for tree-ripe peaches. Their relative desirability was measured by (a) determining the differences in

amount of bruising incurred by the peaches during transit from packing shed to market, (b) determining the rate and amount of cooling of peaches packed in the different containers, (c) and the keeping ability of peaches under cold storage conditions and in different containers. In addition, information on the source and amount of bruising was obtained as well as comparisons between Golden Jubilee and Elberta in respect to keeping ability.

This study has also served to indicate the difficulties involved in reducing rough handling by the pickers as well as defects and merits of containers in packing and in transit to market. In view of these findings and recognizing the necessity of placing high quality peaches on the market it appears at present consistent to recommend the use of containers which are least damaging to the fruit and which lie within economical limits.

Frost Injury to Apples in the Autumn

By A. F. Yeager and E. J. Rasmussen, *New Hampshire Agricultural Experiment Station, Durham, N. H.*

Nearly all references to injury to fruit and foliage from frosts refer to spring frosts. There are two references, however, which mention injury to foliage by early fall frosts. Christ (1) in 1940 mentions damage to foliage. His principal observations concerned the differences in behavior of various varieties which, he states, indicate that those varieties which were late in ripening were inclined to be injured more than those maturing early. However, this statement is hardly consistent with the fact that he lists Wealthy and Williams, two early varieties, as being susceptible. Dutton and Wells (2) observed that foliage on Baldwin, Canada Red and Rhode Island Greening apple trees and Montmorency cherry trees sprayed with bordeaux was severely injured at temperatures of 30 to 32 degrees F on October 5 to 10, while trees sprayed with lime-sulfur 1–40 showed no frost damage. The cherry trees received three applications of spray prior to harvest; the Rhode Island Greening trees received one application of bordeaux only in August. The Baldwin and Canada Red received three applications during the summer. They concluded that the bordeaux sprayed foliage was more susceptible to frost injury than lime-sulfur sprayed foliage. Three possible explanations are given for the frost injury, lower concentrations of cell sap, inhibition of water soluble pentosans, and acceleration of heat radiation.

At New Hampshire Horticultural Farm in 1947 the temperature dropped to 24 degrees Fahrenheit the first of October. This was after the McIntosh had been harvested but before late varieties had matured. The result was a great deal of damage to apple foliage, not however to the same extent on all varieties. McIntosh leaves were generally unhurt, but Baldwin, Northern Spy, Delicious and Golden Delicious were badly injured. This agrees in a general way with Christ (1). The week after the frost, although the fruit itself was not apparently injured, Baldwin began to drop; and at the Horticultural Farm, as was the case in a large proportion of the orchards in the state, Baldwin was mostly picked from the ground. Hormones did not prevent the dropping. The result was low quality fruit, another black mark against the Baldwin variety which is still second in amount of production in New Hampshire. Other varieties, while showing much leaf injury, did not lose their crop. Northern Spy was one of the varieties which frequently suffered severe damage, but there was considerable variation in amount of damage on different trees. Where trees had a light crop or none, the leaves were uninjured; whereas trees with a heavy crop had practically all their leaves killed. Parts of trees bearing a heavy crop were defoliated because of the frost injury, while other parts of the same tree were not injured; hence we must conclude that the size of the crop has considerable effect on susceptibility to frost. This situation existed not only on Northern Spy, but also with other varieties such as Golden Delicious, as noted by Dr. W. W. Smith at Gilford, New Hampshire. These observations refer

to trees that had been sprayed with ordinary mild sulfur for scab control. Weak limbs seemed to be more subject to injury than the stronger ones. At the New Hampshire Horticultural Farm, one block of 80 Northern Spy trees has been sprayed for several years with fermate to determine whether parasites enough to control red mite might build up when no sulfur was used. This whole block was uninjured, although trees on the other side of the road sprayed with the mild sulfur were badly injured.

What is the reason for these differences? The following explanation may or may not be correct. Heavy crops reduce the carbohydrate reserve, thus reducing the osmotic pressure; and lower osmotic pressure means greater susceptibility to freezing injury, according to Levitt and Scarth (3). Fermate, as compared to mild sulfur sprayed trees, might be expected to have more efficient leaves, hence a larger reserve of carbohydrates. Weak branches also have less leaf area and are less efficient manufacturers of carbohydrate.

There is a question as to what the eventual effect of such a freeze on these trees might be. We know what the immediate effect was — loss of crop. And it is reasonable to suppose that the trees which lost their leaves the first of October must certainly produce much less carbohydrates late in the fall than those on which the leaves remained for a month longer. Of course, when this retention of the leaves was associated with the retention of a fruit crop, the additional carbohydrates might well have been used by the fruit and the tree itself may have gone into winter with even less reserves.

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The Storage and Ripening Response of Western-Grown Fruits to Post-Harvest Treatment with Growth-Regulating Substances

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THE studies herein reported were made to measure the ripening response of commercially mature western-grown fruits to post-harvest treatment with the sodium salt of alpha-naphthaleneacetic acid (NAA) and with 2,4–dichlorophenoxyacetic acid (2,4–D). Mitchell and Marth (3) and Southwick (5) have reported increased rate of ripening of detached fruits when treated with growth-regulating substances; Schomer and Marth (4) reported a reduced apple scald development. It would at times be of considerable commercial importance to be able to increase the rate of ripening of detached fruits, especially in the canning industry.

MATERIALS AND METHODS

Both NAA and 2,4–D were used in concentrations of 100 and 1000 ppm in 1 per cent Carbowax No. 1500, and will be referred to as "hormones". The solutions were made up in quantities of 5 gallons and in these the several kinds of fruits, harvested at a good commercial stage of maturity, were immersed for 1 minute. After immersion, the fruits were packaged and placed in refrigerated storage. With some fruits, comparable lots were placed in a ripening atmosphere of 65 or 70 degrees F, and 80 per cent relative humidity immediately after hormone treatment. Certain detailed information on the experimental handling is given under the discussion of each variety.

Where the behavior of the treated fruit was studied during the storage and ripening periods by biochemical means, the respiration rate and the content of soluble pectin, acetaldehyde, and total volatiles were determined as previously described (1, 2).

RESULTS

Apricots:—The Wenatchee Moorpark variety was picked on July 7. The lots of fruit ripened at harvest were a light apricot color in 3 days and reached a prime dessert quality in 5 days. There was no difference in the degree of ripeness between the treated and the untreated lots. Injury as a result of the treatment occurred only in the lots dipped in 2,4–D at 1000 ppm; surface pitting in the form of dark brown flecked areas was quite prominent.

Apricots stored for 10 days at 40 degrees F changed from a light green at harvest to a light apricot color regardless of treatment; after 4 days at 70 degrees all lots were uniformly eating ripe. Soluble pectin increased approximately 100 per cent during storage, and an additional 250 per cent when ripened for 3 days thereafter. Soluble pectin changes, shown in Table I, could not be correlated with post-harvest hormone treatments.

TABLE I—Influence of Hormone Treatments on Soluble Pectin* Content of Apricots and Peaches

Storage Period		Ripening Period		Treatment				
Days	Temperature (Degrees F)	Days	Temperature (Degrees F)	None	2,4-D 100 Ppm	2,4-D 1000 Ppm	NAA 100 Ppm	NAA 1000 Ppm
Wenatchee, Moorpark Apricots								
10	40	–	—	0.1850	0.1725	0.1780	0.1845	0.1975
10	40	3	70	0.4062	0.4460	0.4762	0.4495	0.4895
10	40	5	70	0.4775	0.4600	0 4800	0.4710	0.5100
Elberta Peaches								
0	—	0	—	0.1825	—	—	—	—
0	—	3	70	0.5100	—	0.5200	—	0.5150
9	40	0	—	0.3900	—	0.4100	—	0.4000
J. H. Hale Peaches								
0	—	0	—	0.1160	—	—	—	—
0	—	3	70	0.3825	—	0.4100	—	0.3850
9	40	0	—	0.2500	—	0.2750	—	0.2800

*As per cent calcium pectate.

The respiration rates of treated and untreated apricots are shown in Fig. 1. All samples softened during 10 days' storage without a concomitant rise in respiration rate. The respiration rates at the end of the storage period and after ripening at 70 degrees F for 4 days were quite similar for all lots, excepting the one containing fruit injured by

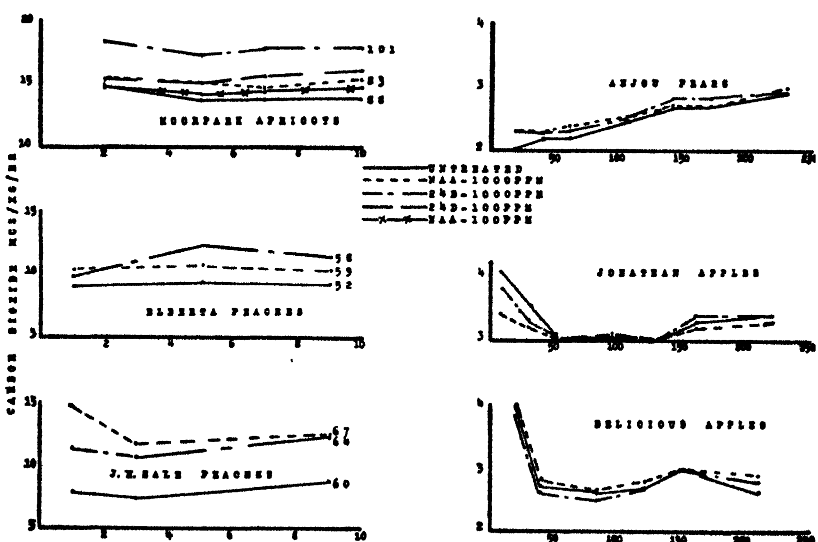

Fig. 1. Effects of post-harvest treatments on respiration rate of apricots and peaches during storage at 40 degrees F and of apples and pears during storage at 31 degrees; respiration rates of peaches and apricots after post-storage ripening at 70 degrees for 3 and 4 days, respectively, are given numerically at the right of the curves. Apricots having the highest respiration rate consisted of fruit showing injury from the 2,4-D treatment.

too strong a concentration of 2,4–D. These data confirm the conclusion reached otherwise, that untreated fruit ripened as fast as that dipped in hormones.

Peaches:—Elberta and J. H. Hale peaches were picked and treated with hormones at 1000 ppm on August 20 and 25, respectively. Fruit ripened at 70 degrees F immediately after hormone treatment softened in 3 days and had prime dessert quality in 5 days. There was no detectable difference in degree of ripeness between the various lots when examined on the 3rd, 5th, 8th and 10th day of ripening. In fruit stored at 40 degrees for 10 days after treatment, there was an indication (Fig. 1) that the hormones may have stimulated the respiration of both varieties. This stimulation was not, however, reflected in a greater degree of ripeness as all lots appeared the same; and at 70 degrees they ripened to best dessert quality with no detectable difference between controls and hormone-treated lots. Organoleptic studies of ripening were confirmed by changes in soluble pectin, data for which are presented in Table I. Peaches treated with 2,4–D at a concentration of 1000 ppm showed no surface injury when ripened immediately following treatment, but those stored at 40 degrees for 10 days and then ripened showed some darkened skin areas.

Southwick (5) found that eastern-grown Elberta peaches had to be harvested prior to best commercial maturity, or in the respiratory preclimacteric stage, to respond to post-harvest hormone stimulation. Elberta peaches, too immature for fresh shipment, were harvested at Wenatchee, Washington, at a firmness of 19 pounds (by pressure test) and dipped in NAA and 2,4–D at 1000 ppm. Control and treated lots alike required 7 days at 70 degrees F to become eating ripe, and had very inferior dessert quality; in 10 days all lots were overripe. Organoleptic tests of this series could not detect any ripening stimulation from the hormone dips.

Bartlett Pears:—In anticipation of still further reducing the ripening period of Bartlett pears through the addition of NAA or of 2,4–D to the hot water baths now commonly used by Pacific Coast canners to speed the ripening of fruit from cold storage, treatments were varied as follows: Fruits harvested August 7 with a firmness of 16.6 pounds, representing a desirable maturity for processors, were composited and stored at 31 degrees F for 42 and 85 days. After these storage periods lots were treated and ripened at 65 degrees F. Treatments consisted of immersing the pears in aqueous solutions, heated to 90 degrees, of NAA and of 2,4–D at 1000 ppm concentration for 10 minutes. Control lots were immersed in 90 degrees water for a like period, simulating commercial practice with cold pears.

Results, determined by organoleptic means, are not given in tabular form, there being no observable difference in the rate of ripening of Bartlett pears when hormones were added to the heated water. After storage for 42 days the fruit ripened to prime dessert quality in 5 days and by 8 days it had become overripe, regardless of treatment. On withdrawal from storage after 85 days, again hormone treatments produced no stimulation in ripening; upon examination of this fruit after being at 65 degrees F for 5, 6, 8, and 11 days, development of

core-breakdown and of pear scald, criteria of earlier ripening, were not different in the treated and untreated lots.

Anjou Pears:—Fruit was harvested August 25 at a good commercial maturity. After treatment with NAA and with 2,4–D, all lots were held at 65 degrees F for 3 days to initiate ripening, and then stored at 31 degrees until April. The rates of respiration shown in Fig. 1 and the changes in firmness, total volatiles, acetaldehyde, and soluble pectin during storage given in Table II fail to indicate any ripening differences that could be correlated with post-harvest hormone treatments.

TABLE II—INFLUENCE OF HORMONE TREATMENTS ON CERTAIN BIOCHEMICAL CHANGES IN ANJOU PEARS, JONATHAN AND DELICIOUS APPLES DURING STORAGE AT 31 DEGREES F

Treatment (Ppm)	Firmness*		Acetaldehyde**		Total Volatiles†		Soluble Pectin‡	
	At 91 Days	At 224 Days	At 91 Days	At 224 Days	At 91 Days	At 224 Days	At 91 Days	At 224 Days
				Anjou Pears				
Check	12.3	7.7	0.30	0.55	275.2	382.4	0.068	0.172
NAA 100	12.6	8.0	0.25	0.48	281.5	362.0	0.070	0.183
NAA 1000	12.4	7.8	0.28	0.42	275.2	375.0	0.069	0.169
2,4-D 100	12.2	7.8	0.32	0.54	253.2	391.0	0.067	0.182
2,4-D 1000	12.2	7.8	0.21	0.54	288.0	375.2	0.071	0.150
				Jonathan Apples				
	At 91 Days	At 221 Days	At 91 Days	At 221 Days	At 91 Days	At 221 Days	At 91 Days	At 221 Days
Check	12.4	10.1	0.19	0.61	288.4	361.0	0.065	0.095
NAA 100	12.5	10.3	0.17	0.69	279.0	293.0	0.061	0.102
NAA 1000	12.7	10.1	0.18	0.61	281.6	312.0	0.064	0.105
2,4-D 100	12.7	9.9	0.18	0.79	265.7	321.5	0.061	0.100
2,4-D 1000	12.6	10.0	0.20	0.56	288.1	322.0	0.064	0.097
				Delicious Apples				
	At 86 Days	At 218 Days	At 86 Days	At 218 Days	At 86 Days	At 218 Days	At 91 Days	At 218 Days
Check	13.4	12.0	0.32	0.65	290.0	357.8	0.057	0.091
NAA 100	13.4	12.2	0.32	0.60	279.0	345.0	0.053	0.097
NAA 1000	13.6	12.4	0.33	0.62	265.7	365.0	0.051	0.092
2,4-D 100	13.5	12.0	0.29	0.59	280.9	338.5	0.054	0.110
2,4-D 1000	13.6	12.0	0.35	0.68	271.0	355.5	0.053	0.107

*As pounds with pressure tester: 5/16-inch plunger with pears; 7/16-inch with apples.
**Acetaldehyde, as mg/100 g tissue.
†Total volatiles, as mg of $Ce(SO_4)_2$ reduced by 100 g tissue.
‡Soluble pectin as per cent calcium pectate.

Apples:—Jonathan and Delicious varieties were harvested on September 4 and 15, respectively, treated with NAA and with 2,4–D, held at 65 degrees F for 3 days to initiate ripening, and then stored at 31 degrees for periodic evaluations until April. Differences in respiration rate shown in Fig. 1 and changes in firmness, total volatiles, acetaldehyde, and soluble pectin shown in Table II fail to indicate that dipping apples in NAA or 2,4–D either at 100 ppm or 1000 ppm, had any consistent influence on the ripening rate. Careful organoleptic tests in December and April detected no greater degree of ripeness in the treated lots than in the controls.

SUMMARY AND CONCLUSIONS

Apricots, peaches, pears, and apples were immersed immediately after harvest in solutions of 2,4–dichlorophenoxyacetic acid and of the sodium salt of a–naphthaleneacetic acid with 1 per cent of carbowax. Bartlett pears were passed through a heated aqueous solution of these chemicals at a concentration of 1000 ppm for 10 minutes following storage at 31 degrees F to simulate ripening methods of the canning industry. Organoleptic tests, as well as biochemical measurements, were used to follow ripening changes.

No correlation could be established between the rate of ripening and any of the post-harvest or post-storage treatments with growth-regulating substances. Visual and organoleptic evidence indicated that the control lots ripened as fast as the treated lots, and biochemical determinations quite generally confirmed this deduction.

It is concluded that the chemicals, used in concentrations up to 1000 ppm and applied after harvest did not measurably stimulate the ripening of western-grown apricot, peach, pear, and apple fruits.

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Three Years' Results With Chemical Thinning of Apples in the Northwest

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During the past 10 years the use of various types of chemical sprays applied during the bloom period for the purpose of reducing fruit set of apples have been reported by many investigators. In general, results obtained have varied so widely as to preclude the possibility of applying the methods and techniques developed in one area to that of another.

In most orchards of the Northwest early and heavy thinning of apples is a necessary and costly operation. Obviously, a chemical spray substitute for hand thinning would be highly desirable. The experiments herein reported were particularly designed to evaluate the commercial feasibility of chemical sprays for apple thinning under conditions prevailing in the Wenatchee district of the Northwest.

Methods

These experiments were conducted in 1945, 1946, and 1947 on the varieties Golden Delicious, and Winesap in orchards located in the vicinity of Wenatchee, Washington. During the 3 years in which these tests were conducted 97 treatments were applied in 21 separate experimental blocks, involving a total of 820 trees. The trees used were average or above in vigor and varied in age from 20 to 35 years. All trees carried a moderate to heavy bloom, and provisions for cross pollination were adequate to good in all of the experimental blocks used. The dinitro compounds were used in a majority of the treatments. These included sodium dinitro cresylate (Elgetol 20), dinitro ortho cresol (DN No. 2), and dinitro ortho cyclo hexyl phenol (DN No. 1).[1] Naphthaleneacetic acid (NAA) was also used extensively. Other materials tested in a limited manner included an oil-wax emulsion (Dow No. 82), morphaline thiuram disulfide (MTD), and a spray mixture of polyethylene polysulfide and zinc dimethyl dithiocarbomate (Goodrite) (5).

The sprays were thoroughly applied with single-nozzle guns operated from a portable power sprayer developing a pump pressure of 600 pounds. Most of the sprays were applied during the bloom period. The exact stage of bloom or fruit development, however, is specified in the tables for each particular treatment. With one or two exceptions, all treatments consisted of 8 to 10 trees randomized throughout the experimental blocks. Fruit set records were obtained by counting from 1,200 to 1,500 blossom clusters on three typical limbs in each tree. Fruit set on these limbs was determined immediately after the June drop. All unsprayed check trees as well as sprayed trees were

[1]In all experimental work involving Elgetol, the "Elgetol 20" was used. A solution of 1 quart per 100 gallons of this material contains approximately the same amount of toxicant as 1 pound of either DN No. 2 or DN No. 1 in 100 gallons.

commercially hand thinned, if in the opinion of the owner, additional thinning was necessary to obtain satisfactory size and quality. Fruit size and yield records at harvest time were obtained, and a careful estimate was made of the amount of bloom on each tree the year following treatment.

RESULTS

In interpreting the effect of various treatments in fruit thinning, it is well to consider the resulting set of fruit with respect to the amount usually regarded as a desirable crop from the standpoint of yield, size, color, and quality. By making extensive counts in a number of orchards it was found that 40 to 45 fruits per 100 blossoming spurs on trees that had a moderately heavy bloom is generally the amount of fruit allowed to remain on the tree after hand thinning. Under Northwest conditions it is felt necessary to remove fruit in excess of this amount if satisfactory fruit size and annual bearing habit are desired.

The data presented in Tables I, II, and III are grouped according to variety. At the present time no explanation can be offered for some of the apparent inconsistencies in the data, and no attempt will be made to discuss the results of each treatment in detail. The following conclusions seem to be supported by the data.

Golden Delicious:—With the exception of one or two cases all treatments resulted in a significant reduction in fruit set (Table I). Due to the relatively large values shown for "difference required" there seems to be only one instance where the difference between any of the treatments is statistically significant. However, there are consistent numerical differences (below the point required for statistical significance) among some of the treatments, and they seem to warrant certain comments and conclusions. Thus, in six comparisons the DN No. 2 as compared with Elgetol (used at equivalent concentration of toxicant) resulted in a consistently greater reduction in fruit set. Also, in 1946 in both the Schell and Bond orchards two applications of Elgetol resulted in greater thinning than a single application of this material. Of considerable interest is the fact that two applications of Elgetol (Bond orchard in 1947) to the same trees made 1 hour apart resulted in virtually the same set reduction as when the second application was made 2 days following the first application.

Within the limits tested, neither the concentration of dinitro sprays nor the time of application during the bloom period resulted in any essential difference in fruit set. The amount of thinning obtained with a given concentration or time of application, however, varied considerably in different orchards and different seasons.

With all Elgetol and DN treatments the increase in fruit size was roughly proportional to reduction in fruit set. In two of the experiments where NAA was included (Bond 1946 and Schell 1946) fruit size was not as large as might be expected from the reduction in fruit set resulting from this treatment.

As pointed out above, all trees including checks were hand thinned relatively early in the season (5 to 7 weeks following bloom). No treatment in any of the blocks resulted in overthinning; in fact only

TABLE I—EFFECT OF THINNING SPRAYS ON FRUIT SET, SIZE, AND SUBSEQUENT BLOOM OF GOLDEN DELICIOUS APPLES

Treatment (Concentration Per 100 Gallons)	Bloom Stage When Sprayed	No. Fruits Per 100 Blossoming Spurs	No. Fruits Per 33 Lbs	Bloom the Year Following (Per Cent)
Bond Orchard—1945				
Elgetol, 2 pts	FB*	83	—	14
Elgetol, 1.5 pts	FB	81	—	11
Elgetol, 1.5 pts	LB**	87	—	17
DN No. 2, 1.0 lb	FB	72	—	6
DN No. 2, 0.75 lb	FB	75	—	5
DN No. 2, 0.75 lb	LB	82	—	6
Unsprayed	—	107	—	4
Difference required†	—	17	—	—
Bond Orchard—1946				
Elgetol, 2 pts	FB	83	66	31
Elgetol, 2 pts‡	FB, LB	77	59	28
NAA, 15 ppm	FB	91	68	23
NAA, 15 ppm	LB	75	75	29
Unsprayed	—	100	75	8
Difference required	—	11	—	—
Bond Orchard—1947				
Elgetol, 2 pts‡	FB, LB	51	—	—
Elgetol, 2 pts‡	FB, FB	49	—	—
Unsprayed	—	65	—	—
Difference required	—	5	—	—
Schell Orchard—1945				
Elgetol, 1.5 pts	FB	74	—	54
DN No. 2, 0.75 lb	FB	69	—	60
NAA, 15 ppm	FB	69	—	51
NAA, 15 ppm	LB	67	—	55
Unsprayed	—	109	—	25
Difference required	—	15	—	—
Schell Orchard—1946				
Elgetol, 2 pts	FB	71	63	79
Elgetol, 2 pts‡	FB, LB	57	57	88
DN, No. 2, 1 lb	FB	65	61	79
NAA, 15 ppm	FB	73	68	54
Unsprayed	—	99	76	52
Difference required	—	9	—	—
Schell Orchard—1947				
Elgetol, 2 pts‡	FB, LB	61	—	—
DN, No 1, 1 lb	FB	62	—	—
Unsprayed	FB	75	—	—
Difference required	—	7	—	—
Pace Orchard—1945				
Elgetol, 1.5 pt	FB	61	—	27
DN No. 2, 0.75 lb	FB	59	—	27
DN No. 2, 0.75 lb	LB	52	—	28
Unsprayed	—	72	—	14
Difference required	—	13	—	—

*First day of full bloom.
**36 to 48 hours later than first day of full bloom.
†Differences in means required for significance at 5 per cent point.
‡Two applications, one at each of the bloom stages designated.

two or three treatments approached the amount of thinning regarded as commercially sufficient, or reduction of fruit set to 40 to 45 apples per 100 blossoming spurs. Most of the treatments resulted in approximately one-half of the amount of thinning required, though the repeat spray treatments in the Bond 1947 and Schell 1946 experiments required less than 0.5 man-hours per tree to complete the thinning, while with untreated check trees in these two orchards 2.0 and 3.3 man-hours, respectively, were required. This ratio of man-hours required between treated and untreated is approximately what might be expected on the basis of fruit set.

In general, most of the treatments (particularly Elgetol), as compared with unsprayed trees, resulted in appreciably greater bloom the year following. Thus, these data support earlier work (1, 2) stressing the effect of chemical thinning sprays in overcoming to a large degree the tendency toward alternate bearing.

Winesap:—Results with this variety are shown in Table II. The dinitro sprays (chiefly Elgetol treatments) generally resulted in a set reduction of 10 to 20 fruits per 100 blossoming spur. Fruit-set on the unsprayed trees in the various experimental blocks was not so consistent as with the Golden Delicious variety. Thus, in three of the orchards where fruit-set on unsprayed trees was less than 50 fruits per 100 blossoming spurs, some of the dinitro treatments resulted in overthinning. Only in two or three instances, however, was the set reduction sufficient to materially affect yield.

In four of the five comparisons with Elgetol the MTD spray resulted in essentially the same degree of thinning. In one instance (Auvil 1945) MTD failed to result in appreciable thinning.

In one experiment (Auvil 1946) NAA at 10 ppm was considerably less effective than Elgetol used at a concentration of 1.4 pints per 100 gallons applied at full bloom. However, in the 1946 Birchmont test these two materials were compared at the above concentration, and the NAA seemed to be considerably more effective than the Elgetol.

No consistent difference in set reduction was obtained in five comparisons when dinitro sprays were put on at full bloom as compared with the same sprays applied 1 to 2 days later. With respect to concentration of the dinitro treatments (five comparisons) the stronger sprays in two instances resulted in appreciably greater thinning, while in the other three experiments there was essentially no difference.

Generally both fruit size and the amount of bloom the year following treatment was greater as a result of the fruit thinning sprays though there were a number of exceptions. It should be borne in mind that the unsprayed trees were all hand thinned relatively early in the season. Such a practice doubtlessly accounts for the smaller differences, particularly in fruit size, than might have been expected on the basis of fruit-set reduction.

Delicious:—It may be seen from the data in Table III that only in the 1947 Bond experiment did Elgetol treatment result in any appreciable thinning of Delicious apples. In that experiment moderate thinning was obtained with a concentration of 1 pint per 100 gallons,

TABLE II—EFFECT OF THINNING SPRAYS ON FRUIT SET, SIZE, AND SUBSEQUENT BLOOM OF WINESAP APPLES

Treatment (Concentration Per 100 Gallons)	Bloom Stage When Sprayed	No. Fruits Per 100 Blossoming Spurs	No. Mature Fruits Per 33 Lbs	Bloom the Year Following (Per Cent)
		Auvil Orchard—1945		
Elgetol, 1.4 pt	FB*	49	110	67
Elgetol, 0.7 pt	FB	51	106	70
Elgetol, 1.4 pt	LB**	56	107	45
Elgetol, 0.7 pt	LB	51	112	47
MTD, 2 lbs	FB	70	109	60
Unsprayed	—	73	121	43
Difference required†	—	17	—	—
		Auvil Orchard—1946		
Elgetol, 1.4 pt	FB	73	88	61
Elgetol, 0.7 pt	FB	84	97	56
NAA, 10 ppm	FB	87	107	47
NAA, 10 ppm	LB	84	101	65
Unsprayed	—	96	99	52
Difference required	—	13	—	—
		Birchmont Orchard—1945		
Elgetol, 1.4 pt	FB	33	78	69
Elgetol, 0.7 pt	FB	33	85	66
Elgetol, 1.4 pt	LB	25	79	77
Elgetol, 0.7 pt	LB	33	81	65
MTD, 2 lbs	FB	35	82	70
MTD, 2 lbs	LB	26	83	69
Unsprayed	—	42	83	53
Difference required	—	6	—	—
		Birchmont Orchard—1946		
Elgetol, 1.4 pt	FB	33	68	85
NAA, 10 ppm	FB	25	67	83
MTD, 2 lbs	FB	35	74	85
Oil-wax, 1 gal	FB	47	76	84
Unsprayed	FB	54	80	76
Difference required	—	9	—	—
		Birchmont Orchard—1947		
Elgetol, 1.4 pt	FB	52	89	—
MTD, 2 lbs	FB	55	106	—
Unsprayed	FB	64	105	—
Difference required	—	7	—	—
		Station Orchard—1945		
Elgetol, 1.0 pt	FB	24	—	—
Elgetol, 1.0 pt	LB	26	—	—
DN No. 2, 0.5 lb	FB	23	—	—
DN No. 2, 0.5 lb	LB	15	—	—
Unsprayed	—	42	—	—
Difference required	—	10	—	—
		Fischer Orchard—1947		
Elgetol, 2.0 pt	FB	21	73	—
Elgetol, 1.0 pt	{FB LB	18	73	—
DN No. 1, 1.0 lb	FB	29	82	—
Goodrite, 0.6 lb	C‡	30	90	—
Unsprayed	—	30	90	—
Difference required	—	9	—	—

*First day of full bloom.
**36 to 48 hours later than first day of full bloom.
†Difference in means required for significance at 5 per cent point.
‡Spray applied 2 weeks after petal fall.

TABLE III—EFFECT OF THINNING SPRAYS ON FRUIT SET, SIZE, AND SUBSEQUENT BLOOM OF DELICIOUS APPLES

Treatment (Concentration Per 100 Gallons)	Bloom Stage When Sprayed	No. Fruits Per 100 Blossoming Spurs	No. Mature Fruits Per 33 Lbs	Bloom the Year Following (Per Cent)
Bond Orchard—1946				
Elgetol, 1.4 pt	FB*	49	—	49
NAA, 10 ppm	FB	51	—	51
NAA, 10 ppm	LB**	44	—	44
NAA, 15 ppm	C†	38	—	29
NAA, 20 ppm	C	27	—	67
NAA, 30 ppm	C	11	—	—
Unsprayed	—	55	—	43
Difference required†	—	9	—	—
Bond Orchard—1947				
Elgetol, 1 pt	FB	50	79	—
Elgetol, 1 qt	FB	53	78	—
Elgetol, 1 pt‡	FB, LB	40	73	—
DN No. 1, 1 lb	FB	54	78	—
Goodrite, 0.6 lb	C	58	86	—
Unsprayed	—	66	86	—
Difference required	—	13	—	—
Auvil Orchard—1946				
Elgetol, 0.7 pt	FB	61	97	42
Elgetol, 1.4 pt	FB	55	92	46
Oil-wax, 1.0 gal	FB	57	93	52
Unsprayed	—	61	100	49
Difference required	—	9	—	—

*First day of full bloom.
**36 to 48 hours later than first day of full bloom.
†Difference in means required for significance at 5 per cent point.
‡Spray applied 2 weeks after petal fall.

and 1 quart per 100 gallons did not result in any additional reduction in fruit set. Two applications (1 pint per 100 gallons) gave an almost ideal set of fruit which required no further thinning. In the 1946 experiments in both the Auvil and Bond orchards an Elgetol spray of 1.4 pints per 100 gallons reduced the set of Delicious by only six fruits per 100 blossoming spurs.

In the Bond orchard (1946) NAA at 10 ppm applied during full bloom failed to thin appreciably, though the same concentration applied 2 days later resulted in a significant reduction in fruit set. In this same experiment NAA sprays applied 15 days after petal fall resulted in very significant thinning which was roughly proportional to the concentration.

Goodrite in the 1947 Bond experiment and the oil-wax in the Auvil orchard failed to have any appreciable effect on fruit set.

NATURE OF FRUIT SET RESULTING FROM SPRAY TREATMENTS

From 30 to 60 "record limbs" of each treatment in the Schell orchard (1945 and 1946 experiments) were selected in order to study in greater detail the nature of the resulting fruit set. Data for the 2 years are averaged and presented in Table IV. Similar data were obtained for certain treatments on Winesap in the 1947 Birchmont experiment and are also shown.

It may be seen from the data that reduction in fruit set from all treatments on both varieties was due to failure of a greater number of flowering spurs (as compared with the checks) to set fruit as well as fewer fruits set per 100 fruiting spurs. This type of thinning resulted in a very uniform distribution of fruit. The greater percentage of fruits originating from center blossoms as a result of all treatments is further evidence (1) that the center or "king blossom" is more resistant than side blossoms to the action of both dinitro and NAA sprays, as well as the MTD treatment.

TABLE IV—EFFECTS OF SPRAYS APPLIED DURING THE BLOOM PERIOD ON THE NATURE OF RESULTING FRUIT SET

Treatment (Concentration Per 100 Gallons)	Bloom Stage When Sprayed	No. Fruits Per 100 Blossoming Spurs	No. Fruits Per 100 Fruiting Spurs	Blossom Spurs Fruiting (Per Cent)	Fruits Originating From Center Blossoms (Per Cent of Total Fruits Set)
		Golden Delicious—1945 1946			
Elgetol, 1.0 qt	FB	68	110	60	58
Elgetol, 1.0 qt*	FB LB	56	106	53	56
DN No. 2, 1.0 lb	FB	65	110	58	61
NAA, 15 ppm	FB	68	119	58	54
Unsprayed	—	101	136	75	40
		Winesap—1946			
Elgetol, 1.4 pt	FB	33	104	32	66
NAA, 10 ppm	FB	25	107	23	57
MTD, 2.0 lbs	FB	34	105	33	52
Unsprayed	—	54	113	52	45

*Two applications, one on first day of full bloom and one 36 to 48 hours later.

INJURY RESULTING FROM SPRAY TREATMENTS

Slight injury occurred to foliage on some of the trees receiving the DN No. 2 treatment. This injury occurred chiefly on trees receiving the stronger concentration of this material (0.75 and 1.0 pound per 100 gallons). It was characterized by crinkling and mottling of some of the young developing foliage and occasionally resulted in dwarfed misshapen leaves. Injury was not so serious in any case that the trees did not soon recover with a foliage system apparently as large and as dense as that of unsprayed trees. The only evidence of injury from Elgetol sprays was a slight yellow mottling of some leaves, and this occurred only when the material was used at a concentration of 1 quart per 100 gallons. Two applications of Elgetol to the same trees caused no injury that might be regarded as commercially important.

The action of the NAA sprays in producing visible injury was erratic, and within the range tested was not necessarily associated with concentration or time of application. In several plots a noticeable "flagging" of the foliage was evident for 5 to 10 days following treatment; however, no dwarfing of the foliage or epinastic effects were observed. In some cases appreciable reduction in fruit set following a full-bloom spray did not occur until 3 to 5 weeks following bloom, or about the beginning of the "June drop".

The MTD, DN No. 1, oil-wax emulsion, or Goodrite did not result in any type of visible injury.

Discussion and Summary

Most of the treatments applied in these experiments appreciably reduced fruit set. All factors considered, Elgetol seemed to be the most consistent and effective. Used at equivalent toxicant concentration, DN No. 2 resulted in a slightly greater reduction in fruit set than Elgetol, though it generally produced somewhat more injury to foliage. However, injury from any of the treatments was not regarded as commercially important. Results with naphthaleneacetic acid were more erratic than with Elgetol, and in several instances fruit size was less than might be expected on the basis of the amount of thinning accomplished. This probably was because the fruit attained considerable size (as was pointed out) before dropping. Nevertheless, results in the present experiments as well as those reported by Hoffman *et al* (4) would indicate promise for this material for thinning apples during the bloom period as well as 2 to 3 weeks later.

In several tests on Winesap morphaline thiuram disulfide (MTD), an organic fungicide, proved about as effective as Elgetol in reducing fruit set. Limited treatments with an oil-wax emulsion (Dow No. 82) and the polyethylene polysulfide plus zimate complex failed to give any significant reduction in set.

Perhaps one of the most significant points revealed in these experiments is the fact that under Northwest conditions Elgetol sprays are much less likely to overthin than under eastern conditions (1, 3). There seemed to be no consistent difference in the action of these sprays on the varieties tested. Only when fruit set on unsprayed trees of the Winesap variety fell below 50 apples per 100 blossoming spurs did the dinitro spray result in overthinning. With Delicious, Golden Delicious, and Winesap, where fruit set was relatively heavy many of the treatments failed to thin enough. With Golden Delicious, which sets consistently heavy crops under most conditions, the data indicate that two applications would probably be required to approach the desired amount of thinning. This procedure may be necessary under some conditions with Delicious and Winesap. Elgetol sprays stronger than 1 quart per 100 gallons were not tried, but it is probable that injury under some conditions might offset any advantages gained in greater thinning.

Within the range tested neither the concentration of Elgetol spray nor the time of application during the bloom period resulted in any essential difference in reducing fruit set. These results are in agreement with those obtained under eastern conditions (1). The fact that appreciable set reduction was obtained when Elgetol spray was applied from 1 to 3 days following full bloom would indicate that a large number of flowers already fertilized are killed by this material.

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Relative Humidity for Storing Dates at Different Temperatures

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Dates are marketed with moisture content varying over a considerable range, depending partly on the variety and partly on the wishes of the packers. The extreme range extends from well below 20 per cent for very dry dates or date products to about 40 per cent for the very moist, highly perishable ones, but most are marketed with an intermediate moisture content. Unless moisture-proof containers are used, dates differing by only a fraction of this range obviously can not be stored together without the drier lots absorbing or the wetter lots giving off moisture, or both.

Methods

Relative humidities in equilibrium with dates of various known moisture content were found by enclosing individual fruits in a small space together with humidity-sensitive elements. The atmospheric relative humidity at equilibrium was determined with an Aminco-Dunmore electrohygrometer at temperatures which remained constant within 1 degree F while any given determination was in progress.

Results

Two curves were developed from data obtained at 75 degrees F (1). One curve applies to the Deglet Noor, the most extensively grown variety in the United States, and the other to all the other varieties tested, including Khadrawy, Halawy, Barhee, Maktoom, Medjhool, Saidy, and Zahidi. The two curves are nearly parallel, but Deglet Noor dates in equilibrium with a given relative humidity will have a moisture content about 4 per cent higher than the varieties that fit the second curve.

Upon plotting the relative humidity against the logarithm of the moisture content the values fell along the two straight lines shown in Figs. 1

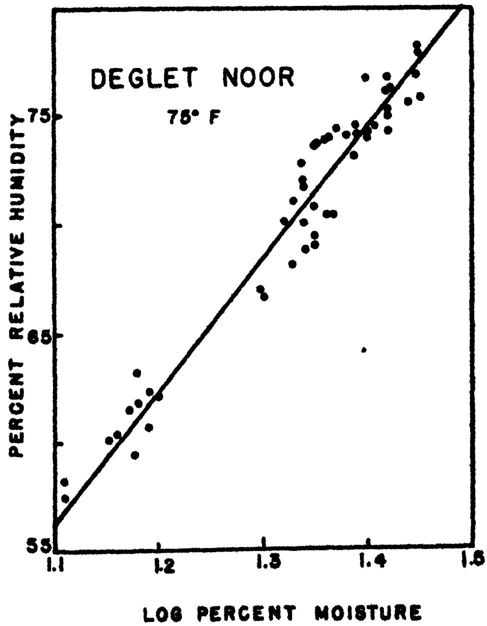

Fig. 1. Relative humidity of atmosphere in equilibrium with Deglet Noor dates having various percentages of moisture, at 75 degrees F.

and 2. Fig. 1 contains the results obtained with Deglet Noor, and Fig. 2 those with the remaining varieties named above. Neither of these lines may be extrapolated indefinitely, since they are not oriented so as to give 100 per cent relative humidity at 100 per cent moisture content, but the fit is satisfactory within the limits used.

Relative humidities in equilibrium with dates, with sugar solutions, and with sulfuric acid solutions were determined at 75 degrees F, and also at 32 degrees. Suitable temperature corrections for date storage humidities have been prepared (1). The relation between the equilibrium relative humidities at the two temperatures is illustrated in Fig. 3. The 15 points determined with dates fit a straight line with a coefficient of correlation of +.994. The points obtained with three concentrations of fructose and one of sucrose fit a straight line (r =

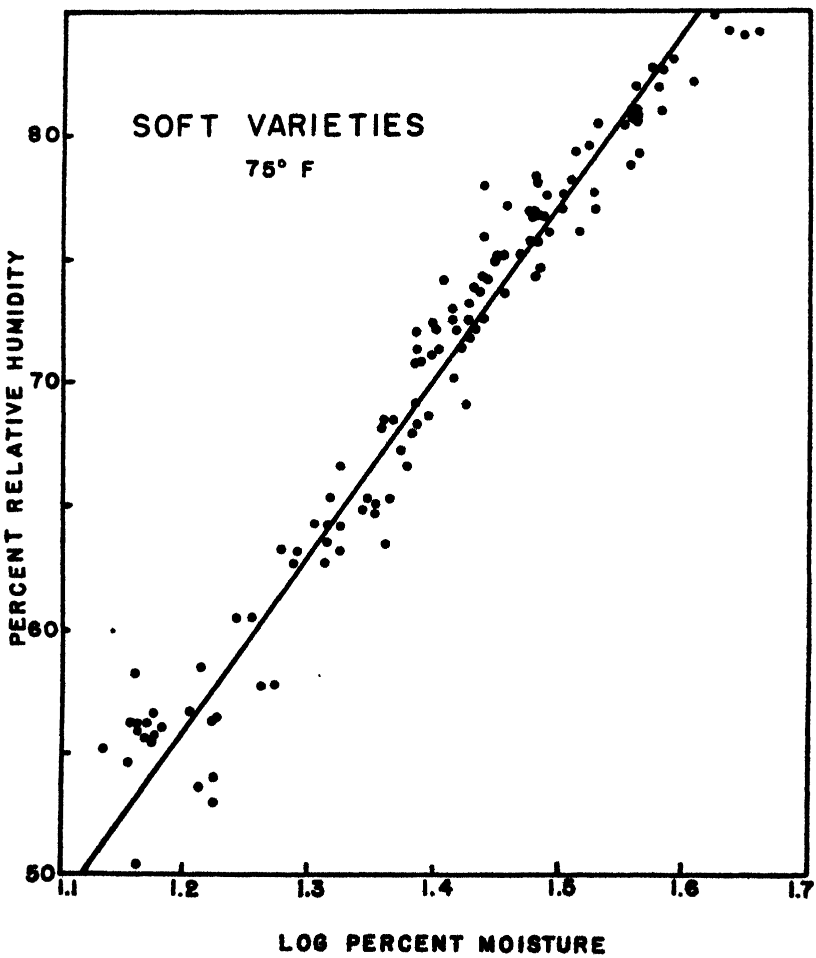

FIG. 2 Relative humidity of atmosphere in equilibrium with soft date varieties having various percentages of moisture, at 75 degrees F.

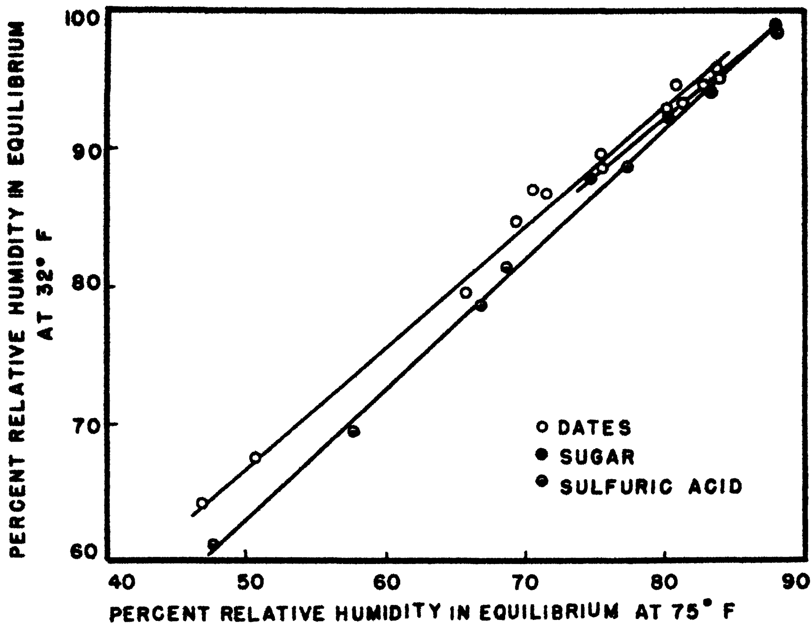

FIG. 3. The relation between relative humidity of atmosphere in equilibrium with dates, with sugar solutions, and with sulfuric acid solutions, at 75 degrees F, and at 32 degrees.

+.991) which for all practical purposes may be assumed to be identical with that for the dates. The relative humidity in equilibruim with six concentrations of sulfuric acid fit a straight line (r = +.998) slightly removed from those for the dates and sugars. Within the range investigated the difference between the equilibrium values at the two temperatures is slightly greater at low humidities than at high ones for all the materials used.

SUMMARY

Within the limits investigated the points obtained by plotting the logarithms of per cent moisture in dates against the per cent relative humidity at equilibrium fall along a straight line.

The relative humidity in equilibrium with dates of various moisture content, with sugar solutions, and with sulfuric acid solutions is appreciably higher at 32 degrees F than at 75 degrees. The difference is slightly greater at humidities in the lower part of the range investigated than in the upper part. The difference caused by this temperature differential was from about 10 to 17 in relative humidity percentage.

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A Study of Maturity Indices for McIntosh Apples

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A great deal of investigational work has been done on what indices of maturity are most dependable for picking apples for cold storage. There is not very general agreement among the various investigators as to the reliability of any one method of determining apple maturity.

This study was conducted to try to determine which methods of measuring apple maturity were most applicable to McIntosh apples that were to be held in cold storage until March.

Methods

Firmness of the apples was determined with a Magness-Taylor pressure tester. Surface color was estimated according to the average amount of full red color on the fruits. Ground color was determined with a color chart prepared by the California State Department of Agriculture. Soluble solids were determined with a portable Zeiss refractometer.

Respiration measurements were made at 74 degrees by the conventional titration method on approximately 3-kilo samples. Respiration measurements were started 24 hours after picking. The apples in cold storage were held at 32 degrees F.

The apples were picked from the same orchard during the 7-year period. Upon removal from storage they were examined for firmness, soluble solids, eating quality, shriveling and brown core. The apples were allowed to stand 2 days at room temperature following storage to determine scald.

Results

One- or 2-bushel samples of apples picked at each indicated picking date were stored until March 1. The data on the apples following storage appear in Table I. The "best pickings" were judged on the basis of eating quality, firmness, and general freedom from storage disorders.

Fruit Firmness:—It has been recommended that McIntosh apples be picked at a pressure test of 15 pounds (3). An examination of Table I indicates that the "best pickings" of McIntosh over a 7-year period ranged between 15.0 and 17.7 pounds. This is too wide a range to make this index a reliable one. It has already been pointed out that nitrogen level may play a part in fruit firmness and one would have to define the firmness index for various nitrogen levels (9). The fruits in this study came from relatively low nitrogen level trees. Haller (4) has pointed out other limitations of the pressure test as a means of telling when to pick apples.

Ease of Separation:—In 6 out of 7 years the apples that kept best were rated as "easy" in separation from the fruit spurs. This meant that the apples came off the spurs with a very slight rolling action in the picking operation. While this index has some value, it is too in-

definite and too subjective to be of value in telling a novice when to pick this variety. This index is further complicated by the use of hormone sprays.

Surface Color:—It seems generally agreed among investigators that this index is of little value in determining when to pick apples. In this study the best pickings ranged from 50 to 90 per cent full red coloration.

Ground Color:—The change in ground color from green to yellow is used in many quarters as an index of when to pick apples. Its value is limited on a variety like McIntosh by the relatively slow change. The ground color on the best pickings ranged from 2 to 3 but a ground color of 2½ to 3 on the color chart could be classed as a fair index of when to pick this variety.

Soluble Solids:—As apples mature on the tree the soluble solids increase. The soluble solids in the best pickings ranged from 10.5 to 13.1 per cent. This range is too large to permit one to consider this as a reliable index of when to pick McIntosh. Furthermore, the change in soluble solids in a given season is rather slow. Sampling errors on a given day are often bigger than differences from one sampling day to another.

Days From Full Bloom:—It has been recommended that McIntosh be picked for "optimum maturity" at 135 to 140 days from full bloom with 130 as a minimum (5, 10). Table I shows that the best pickings were made from 123 to 157 days from full bloom. The average was 133 days from full bloom. This range was entirely too large to depend on this index for picking McIntosh at Ithaca, New York. While the average figure coincides very well with the recommended value, such averages are meaningless. During the 1945 growing season McIntosh was in full bloom on April 15 (usual time May 15) and yet the apples were harvested at about the usual time. The recommendation noted above may hold in some areas with relatively uniform growing conditions from season to season but did not hold in this study. On the other hand, Brooks (1) has reported that in California where growing conditions are relatively uniform from year to year that heat summation records had to be kept in order to project ahead to the harvest date for pears.

Calendar Date:—The best pickings were made in the range from September 17 to September 27. This range is too large to make calendar date a good index of when to pick. On the other hand, calendar date proved to be a more reliable index of when to pick than did days from full bloom.

Respiration Rate:—Kidd and West (6) have reported that most English varieties should be picked just as the climacteric rise begins. On the other hand, Phillips (8) has reported that McIntosh should be harvested after the climacteric peak has been passed. In this study at least half of the apples had abscissed by the time the climacteric peak had been passed. Ezell and Gerhardt (2) question the validity of respiration measurements made 24 hours after the harvest as an index of fruit maturity. They present the view that such measurements ex-

TABLE I—KEEPING QUALITY OF McINTOSH APPLES IN STORAGE AS RELATED TO MATURITY INDICES AT HARVEST

	At Harvest						After Storage (March 1)								
Harvest Date	Firmness (Lbs)	Ease of Separation	Surface Color (Per Cent)	Ground Color	Soluble Solids (Per Cent)	Days From Full Bloom	Firmness (Lbs)	Ground Color	Soluble Solids (Per Cent)	Eating Quality	Brown Core (Per Cent)	Shrivelling	Scald (Per Cent)	Best Pickings	Lot in First Quarter of Climateric Rise
							1941–42								
Sep 3	17.2	Medium	30	2–2½	11.3	117	11.9	2½–3	12.2	Poor	6.0	Severe	100.0	—	—
Sep 10	16.0	Easy	40	2–2½	11.6	124	12.3	2½–3	12.1	Poor	0.0	Severe	100.0	—	—
Sep 17	16.0	Easy	60	2½–3	12.7	131	12.4	3	12.7	Fair	0.0	Slight	100.0	—	—
Sep 24	15.3	Easy	75	2½–3	13.2	138	12.6	3½	13.1	Good	0.0	Slight	53.3	**	*
Oct. 1	12.7	Easy	85	3	13.2	145	11.5	4	12.7	Good	0 0	Very slight	23.0	*	—
Oct 9	13.0	Very easy	95	4	13.4	152	10.7	4	13.0	Good	0.0	Very slight	0.0	—	—
							1942–43								
Aug 27	20.0	Medium	50	1½–2	11.0	114	10.6	2	11.0	Poor	95.0	Very severe	100.0	—	—
Sep 3	19.1	Medium	60	2	11.0	121	10.9	2–2½	11.0	Poor	45.0	Severe	100.0	—	—
Sep 10	17.4	Medium	60	2	11.2	128	10.7	2½	11.2	Poor	70.0	Severe	90.0	—	—
Sep 17	16.8	Easy	75	2½–3	11.3	135	11.3	2½–3	11.2	Fair	20.0	Slight	80.0	**	*
Sep 21	17.2	Easy	85	3	11.8	142	10.2	3	11.4	Good	10.0	Slight	100.0	*	—
Sep 24	17.3	Easy	85	3	12.0	145	10.5	3–4	11.6	Good	20.0	Slight	90.0	—	—
Oct 1	15.5	Easy	90	3–4	12.0	152	10 0	4	12.0	Mealy	5.0	Very slight	70.0	—	—
Oct 8	13.6	Very easy	95	4	11.8	159	9.8	4	12.2	Mealy	10.0	Very slight	0.0	—	—
							1943–44								
Aug 30	20.3	Difficult	25	1½	11.0	98	13.0	2–2½	11.4	Very poor	60.0	Severe	100.0	—	—
Sep 3	19.8	Medium	30	2	11.1	102	13.7	2	11.6	Very poor	55.5	Severe	100.0	—	—
Sep 10	18.4	Medium	40	2	11.2	109	13.5	2	11.7	Very poor	50.0	Moderate	93.3	—	—
Sep 17	18.0	Medium	75	2–2½	11.6	116	13.4	3–3½	11.6	Poor	35.2	Slight	100.0	—	—
Sep 21	17.4	Medium	90	2½–3	12.0	120	12.6	3	12.2	Fair	20.0	Slight	76.2	*	*
Sep 24	17.7	Medium	90	3	11.7	123	13.0	4	12.2	Good	30.0	Slight	42.0	**	—
Sep 28	16.6	Easy	95	3–4	12.0	127	12.3	4	13.0	Mealy	34.6	Slight	0.0	—	—
Oct 1	15.7	Very easy	95	4	12.2	130	11.7	4	—	Mealy	30.0	Slight	35.0	—	—
Oct 5	16.0	Very easy	95	4	13.2	134	11.8	4	13.2	Mealy	20.0	Slight	0.0	—	—
							1944–45								
Aug 30	20.2	Medium	10	2	10.5	105	11.5	2	10.8	Very poor	100.0*	—	100.0*	—	—
Sep 6	20.7	Medium	15	2	10.4	112	12.7	2	11.1	Very poor	97.0	—	100.0	—	—
Sep 13	20.3	Medium	26	2	10.8	119	11.7	2	11.2	Poor	93.0	—	100.0	—	—
Sep 19	17.3	Easy	28	2	11.8	125	11.3	2½	11.8	Poor	95.0	—	100.0	—	—
Sep 22	15.8	Easy	40	2	11.7	128	11.4	2½–3	11.9	Fair	6.8	—	2.8	**	*
Sep 26	16.4	Very easy	60	2–2½	12.4	132	10.2	3	12.1	Fair	6.8	—	2.4	*	—
Sep 29	15.5	Very easy	60	2–3	12.1	135	10.9	3–3½	12.4	Fair	1.7	—	1.3	—	—
Oct 6	14.4	Very easy	70	3	12.9	142	10.5	3½	12.8	Mealy	1.8	—	3.6	—	—

							1945–46								
Sep 10	16.8	Medium	25	2	11.0	141	11.1	2½–3	12.0	Poor	16.0	Moderate	100.0	—	—
Sep 17	16.5	Medium	25	2½	—	148	11.4	2–3	12 2	Poor	30.0	Slight	80.0	—	—
Sep 24	17.7	Easy	60	2½–3	11.0	154	10 5	2–3	11 8	Poor	32.7	Moderate	17.3	—	—
Sep 27	17.3	Easy	60	2½–3	12.2	157	10.5	3–4	11.3	Fair	37.5	Moderate	12.5	**	*
Oct 1	16.7	Easy	60	3–4	12.8	164	10.5	4	13.0	Fair	24.0	Slight	0.0	*	—
Oct 5	16.9	Easy	80	4	13.2	168	10.5	4+	12.6	Mealy	50.0†	Slight	0.0	—	—
							1946–47								
Sep 3	16.1	Medium	25	1½–2	9.2	111	10.6	—	—	Very poor	61.0	Severe	96.0	—	—
Sep 10	15.8	Medium	35	1½–2	11.0	118	10.1	—	—	Poor	48.0	Severe	44.0	—	—
Sep 17	15.1	Medium	50	2–2½	11.2	125	10.8	—	—	Fair	20.0	Slight	6.0	—	—
Sep 21	16.1	Easy	75	2½	11.1	129	11.1	—	—	Fair	6.0	Slight	4.0	—	—
Sep 24	16.1	Easy	80	2½	11.4	132	10.8	—	—	Good	16.0	Slight	2.0	**	*
Sep 28	15.1	Easy	85	2½	11.6	136	10 6	—	—	Good	20.0	Very slight	0.0	*	—
Oct 1	15.5	Easy	85	2½–3	11.7	139	10 7	—	—	Fair	8.0	Very slight	0.0	—	—
Oct 7	14.0	Easy	95	3–4	11.8	145	10.3	—	—	Fair	10 0	Very slight	0 0	—	—
Oct 15	14.0	Very easy	95	3–4	12.2	152	9.5	—	—	Mealy	0.0	Very slight	0.0	—	—
							1947–48								
Sep 3	16.9	Difficult	15	1½–2	10.1	104	11 9	—	—	Poor	42.5	Severe	100.0	—	—
Sep 10	16.6	Medium	20	2	10.2	111	11.1	—	—	Poor	26.3	Moderate	100.0	—	—
Sep 17	16.0	Medium	25	2	10.6	118	11.3	—	—	Poor	12.0	Slight	6.0	—	—
Sep 24	15.0	Easy	50	2–3	11.0	125	10 5	—	—	Good	0.0	Slight	82.05	**	*
Oct 2	13.8	Easy	80	3–4	11.4	133	9.9	—	—	Fair	0.0	Slight	54.16	*	—

*Data taken May 1.
†Some mealy breakdown similar to brown core.

press a physiological artifact and assume from their studies that the apples on the tree do not go through a climacteric rise. Kidd and West (7), however, found that apples did go through such a rise while attached to the tree.

In this study 3-kilogram samples of apples for each picking were held at 74 degrees for respiration measurements. In Fig. 1 appear the data on respiration for each picking over the 7-year period. In other words, each determination on Fig. 1 represents the data obtained on individual pickings made 24 hours after harvest. The normal climacteric rise is apparent in each case.

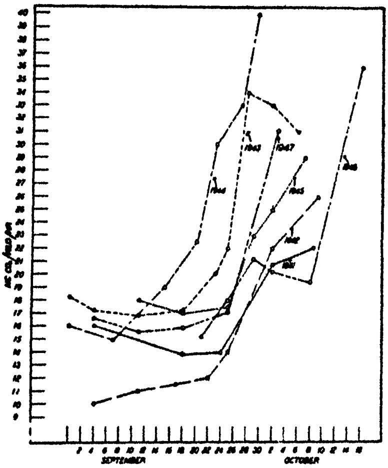

FIG. 1. Effect of maturity at harvest on respiration rate of McIntosh apples at 74 degrees F (respiration determinations made 24 hours after harvest).

An attempt was made to correlate the "best picking" with its position on the climacteric curve. Only a very general statement can be made on such a correlation. In general the best picking was made just as the climacteric rise began or shortly after it began. In no case was the best picking made after the apples had passed through the first quarter of the climacteric rise.

It should be noted here that this correlation was always made "in retrospect". It is questionable whether this index could be a useful tool in predicting when to pick apples. It is next to impossible to predict in a given year when the climacteric rise is going to begin. Secondly, it is strictly a laboratory technique. The value in this technique is that these data suggest that once the climacteric rise has begun with this variety the apples should be picked very soon.

The climacteric "break" or initiation of the climacteric rise usually can be discerned within a 3- or 4-day period. From this standpoint it is probably the most accurate of the maturity indices that were studied.

Fig. 2 presents the respiration data in full during 1943. The respiration rates of each picking for periods of from 4 to about 10 days following harvest were measured. It illustrates that up until September 22 all pickings were made prior to the climacteric rise. The October 5 picking was made after the climacteric peak had been passed.

Starch-Iodide Test:—Data on the starch losses in the fruits as they matured on the tree were obtained by the starch-iodine test in some years. The results were so extremely erratic that they are not presented. Variations on any one sampling date were entirely too large to make the test of any value in this work.

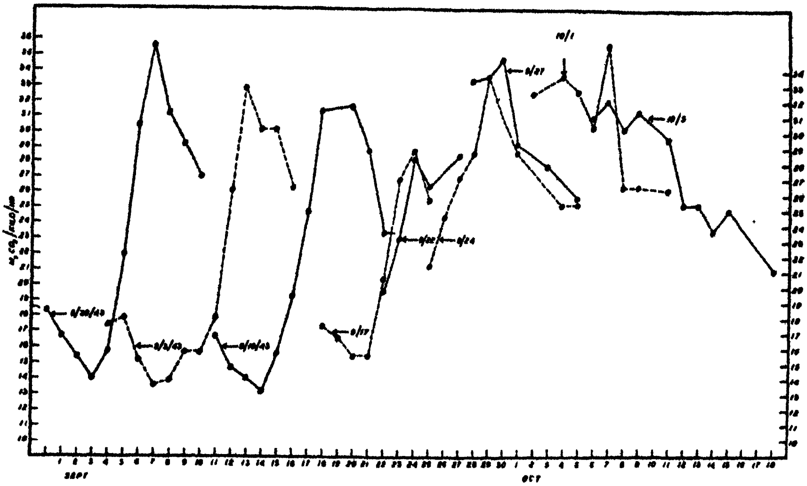

FIG. 2. Respiration rates of successive pickings of McIntosh apples at 74 degrees F in 1943.

DISCUSSION

Variations in the pressure test were too great from year to year to use firmness at harvest as an index of when to pick McIntosh in this study.

Ease of separation from the spur could only be classed as a "rough" or crude guide as to when to pick McIntosh.

The amount of surface color is a poor index of when to pick this variety.

Ground color was among the best indices of when to pick McIntosh. While there was some range in ground color in the "best pickings" from year to year, it is thought that a new color chart prepared by F. W. Southwick based on the actual ground color of McIntosh apples will further improve this index.

The range in soluble solids from year to year was too great to give this test much reliability.

The "days from full bloom" index was too variable to give this test value for McIntosh in this test. The best pickings were made in the range of 123 to 157 days.

The calendar date for the best picking had a 10-day range. This range is too great to serve as a guide for picking from year to year although it served as a better guide than days from full bloom.

The best pickings were made just at or just following the beginning of the climacteric rise in respiration. This index probably had the least variation from year to year of any of those studied. For experimental studies it probably should be one of the indices of maturity used. It would seem to have little practical application.

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A Multiple Chamber Pressure Unit for Respiration Studies

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Several methods of measuring the rate of respiration of fruits and vegetables have been used in horticultural research. The ascarite gravimetric system is one of the older methods and Masure (4) has compared this method with the more recent methods of Heinicke and Hoffman (3). The absorption of the evolved carbon dioxide, from samples, in KOH or NaOH solutions in a specially constructed tower is also an older method. However, the Heinicke-Hoffman system, as mentioned above, provides many refinements over the older absorption tower methods. Recently Claypool (2) has devised a rapid colorimeteric method for tests of short duration and with small samples. Most of the respiration studies reported to date have involved the measurement of relatively few samples per given test.

This article describes a pressure system that will measure the respiration rate of 12 samples per test. A pressure system presents several points of merit. The unit is easy to construct and to maintain in operating condition. The system is adaptable to a wide range of fruits and vegetables, since the rate of air flow can be conveniently adjusted to the size and type of sample being tested.

Description of Apparatus

The respiration chambers consist of 12 cast iron chambers mounted on a steel rack (Fig. 1). These chambers, which have a volume of 0.75 cubic feet, were originally designed by the Army Air Corps for testing aviation instruments. There are four, ⅛-inch thread outlets in the base of each chamber and two plexiglas windows in the iron lid. The lid is easily sealed against a synthetic rubber gasket by two hexagonal nuts tightened with a socket wrench.

Pressure is supplied from a 40-pound air pressure line. The pressure is reduced to 4 pounds before passing through a scrub-tower, where all carbon dioxide is removed from the incoming air. A steel wool air filter might also be needed if the air supply contains small droplets of oil or other impurities. This should be so arranged that the air passes through this filter before entering the scrub-tower.

The scrubbing tower, for removing the carbon dioxide, consists of a cast iron chamber fitted with a 3½-inch glass cylinder, 42 inches long. The glass cylinder extends to within ½-inch of the base of the chamber, and is filled with 10 pounds of 6 millimeter glass tubing cut to ¼-inch lengths. A porcelain plate, mounted on rubber stoppers, supports the glass in the tower. The chamber is coated with asphalt paint to reduce corrosion of the chamber by the concentrated NaOH used to absorb the carbon dioxide. During a test, the NaOH is forced from the chamber into the tower. The extensive surface of the cut glass, bathed with the concentrated NaOH, results in efficient absorption of carbon dioxide from the incoming air.

Uniform temperature of the air is secured by a 50-foot copper coil

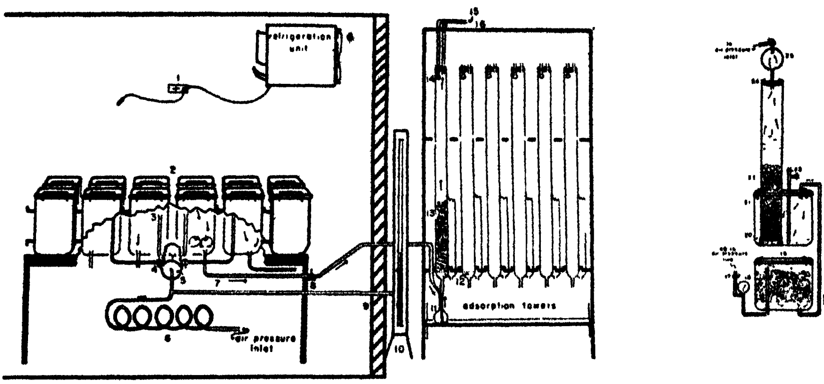

FIG. 1. Diagram of a multiple chamber pressure unit for respiration studies.

1. Thermostat
2. Cast iron chambers
3. Cut-away showing inlet and exhaust connections
4. Pinch clamp for adjusting air flow.
5. Air distribution cylinder.
6. Copper coil for equalizing temperature of air.
7. Exhaust line to absorption towers.
8. Line clamp for alternating the two twelve-chamber units
9. Wall of constant temperature room
10. Water manometer for adjustment of air flow to chambers
11. 500 m.l. volumetric flasks.
12. Frittered glass disk
13. Glass absorption tower
14. Perforated glass bulb for rinsing tower with distilled water
15. Distilled water line
16. Air line exhaust
17. Valve to regulate incoming air pressure
18. Pressure gauge
19. Iron chamber with steel wool filter for air supply.
20. Porcelain plate
21. Asphalt coated iron chamber with NaOH solution
22. Cut glass in scrub tower
23. Refill and drain connection
24. Rubber stopper, taped at top of scrub tower
25. Kjeldahl bulb

mounted in the temperature control room, which houses all of the respiration chambers. All inlet and exhaust lines for the respiration chambers are ¼-inch copper tubing. Carbon dioxide-free air is distributed uniformly to each of the 12 chambers through copper tubing from a small 6-inch-air distribution cylinder, 2½ inches in diameter. The rate of air-flow of each chamber is regulated by a pinch clamp on each line near the distribution cylinder. The connections to each chamber are made with ⅛-inch threaded brass nipples with compression fittings for ¼-inch copper tubing. The remaining two holes in each chamber are sealed with ⅛-inch threaded steel plugs.

A 6-foot manometer containing water is connected to the air distribution cylinder. This affords a sensitive method of varying the rate of air flow to all chambers. A pressure of 1.8 pounds at the distribution cylinder will result in an air-flow rate of 3.5 cubic feet of air per chamber per hour. The pressure within each chamber is approximately 1 pound.

The carbon dioxide released by the fruit or vegetable sample is absorbed in glass towers containing frittered glass plates at the base to

aid in spreading the air stream. These absorption towers are located outside of the controlled temperature room. A 0.1 or a 0.05 Normal NaOH is used for absorption and the concentration best suited would depend on the kind or amount of produce being tested, as well as the length of the test. When a test is completed, the pressure is released and the NaOH solution in the separate towers drains into the 500-milliliter volumetric flask at the base of each tower. Each tower is

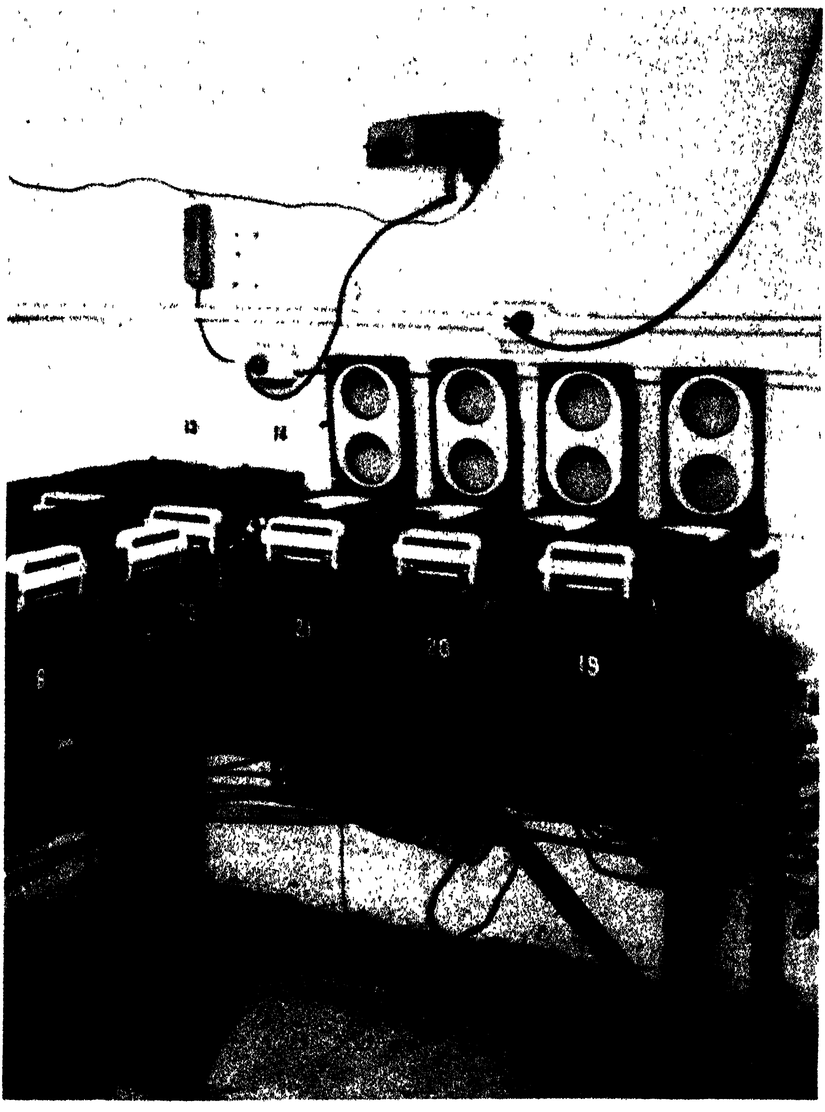

FIG. 2. A multiple chamber pressure system consisting of two 12-chamber units connected in parallel to the same exhaust line.

thoroughly rinsed with distilled water before the volumetric flasks are removed. A barium chloride solution is added to the flasks to precipitate the sodium carbonate formed during the test. The flasks are filled to volume and an aliquot of the clear solution is titrated with hydrochloric acid. By difference and chemical equation, the milligrams of carbon dioxide evolved from the sample during a test can be determined.

The pressure respiration system at The Ohio State University contains two of the above described systems. The two-unit system is connected in parallel (Fig. 2) to the absorption towers so that alternate test runs can be made each hour. Both of these units are located in a constant temperature control room designed by Childers and Brody (1). The temperature in this room can be controlled within plus or minus 1.5 degrees Fahrenheit.

One of the major advantages noted with the multiple unit respiration system as described is the opportunity of increasing the number of replicated samples which can be tested concurrently. In addition, the size of the chamber allows samples of from 1 to 3 kilograms to be used for each replication and for each treatment. Both of these factors tend to aid in a more accurate interpretation of the results of respiration studies than where small samples and inadequate replication must be utilized.

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Respiration of Citrus Fruits in Relation to Metabolism of Fungi. II Effects of Emanations of Penicillium Digitatum, Sacc. on Lemons at Different Stages of Ripeness

By J. B. Biale, *University of California, Los Angeles, Cal.*

Several years ago a report was issued from this laboratory (1) dealing with the marked effects of minute amounts of vapors produced by the common green mold (*Penicillium digitatum,* Sacc.) on the acceleration of respiration rates and on the rapid disappearance of chlorophyll from dark green lemons. Thus far the published results were limited to fruit subjected to the vapors of the fungus immediately after harvesting and washing in the packing house, and, also, to lemons of one color grade. The purpose of this paper is to include studies on lemons at different periods throughout the storage life and to compare the effects of mold emanations on fruit of the several color grades.

Materials and Methods

The methods and experimental procedures were described previously (1). Briefly, 50 uniform commercially graded lemons were subjected to emanations of one moldy lemon inoculated from a pure culture of the common green mold. A constant stream of air, usually 350 ml/min, was passed through the container with the moldy lemon and over the sound fruit. The carbon dioxide production of the sound lemons only was measured with ample time provided for passing CO_2 free air before each respiration determination.

Experimental Results

Effects of Fungal Emanations on Respiration of Lemons at Different Periods during Storage:—Two experiments were designed for the purpose of comparing mold vapor effects at regular intervals with controls subjected to air free of mold emanations. In experiment 1 the storage time was 3½ months while in experiment 2 it lasted 7 months.

In experiment 1 lemons picked on July 11 and washed on July 14 were placed the next day at 15 degrees C (59 degrees F) under a constant stream of air which was tested to be free of active emanations. Jars 1 and 2 weighing 5,250 and 5,150 grams respectively served as controls, while jars 3, 4, and 5 weighing 5,220, 5,125, and 5,170 grams, respectively, were exposed to mold vapors at different dates. The response in CO_2 production by sound lemons to green mold emanations is shown in Fig. 1. Jar 3 was subjected to the fungal emanations on July 22, jar 4 on September 3, and jar 5 on October 16. In each case the moldy lemon was one fourth to one half covered by the fungus when first introduced, and it was replaced as soon as the entire surface was attacked. Prior to differential treatment the rates of respiration were nearly the same in all jars. The effects of the active vapor were immediate and at the peak the percentage in-

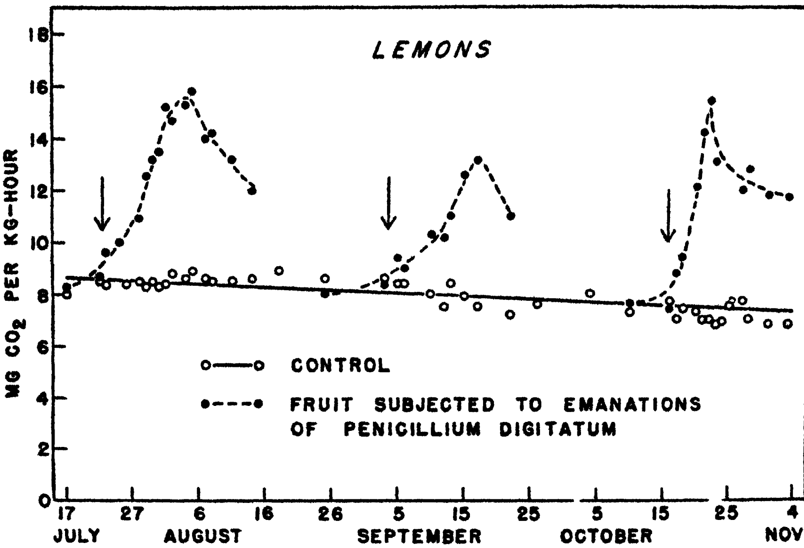

FIG. 1. Effect of emanations of *Penicillium digitatum* on CO_2 production of lemons during storage period of 3½ months.

crease in respiration of the treated lemons over the controls was 88, 67, and 105 for jars 3, 4, and 5, respectively. The ratings for jars 3 and 5 resembled closely the findings in a number of other experiments. Coupled with accelerated rates of respiration the stem ends of the treated lemons became loose in the early stages of storage. These symptoms are considered to be an index of lowered fruit vitality and keeping quality.

In order to obtain a more conclusive idea of the effects of green mold vapors on storage life experiment 2 was planned so as to subject at least one jar each month to emanations. The lemons for this experiment were picked on July 15, washed in the packing house on July 17, and regraded in the laboratory the same day. Twelve jars with 50 dark green lemons in each were placed on air at 15 degrees C. The mean weight for the 12 fruit samples was 5,865 grams with a maximum deviation of ±400 grams from the mean. Ordinarily the weight variation of the samples was below ±5 per cent, which is of the same order of magnitude as the variability in carbon dioxide evolution. These deviations are small as compared with the increases in respiration rates of fruit under mold vapor. The magnitudes of the response at different periods throughout storage life are shown in Fig. 2.

In examining this figure it is of interest to note the marked decrease in CO_2 production of the control jars resulting in a reduction of about 50 per cent in February as compared with the beginning of the experiment in July. The absolute values for CO_2 production of the treated fruit at the peak also dropped from over 18 mg/kg-hour for the July sample to about 8.5 mg/kg-hour in January. However, the relation-

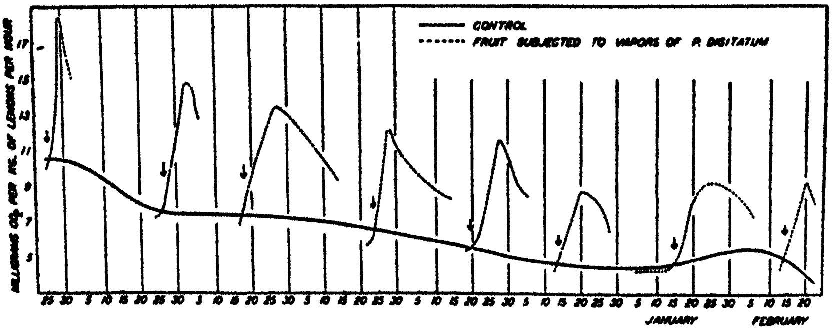

FIG. 2. Effect of emanations of *Penicillium digitatum* on respiration of lemons during storage period of 7 months.

ship between the respiration of the lemons subjected to emanation and the control did not materially change throughout storage life. In the July sample the increase in CO_2 production of the treated over the control amounted to 76 per cent, while 6 months later it was 85 per cent.

The control samples kept exceptionally well for 7 months as compared to a maximum storage life of 6 months under commercial conditions. By contrast, the lemons subjected to green mold emanations had a much shorter storage life. Jar 1 placed under active vapors on July 25 exhibited besides an immediate and sharp rise in CO_2 production also a rapid rate of yellowing. On August 5, 10 days after commencement of treatment, the lemons in jar 1 were classified as 35 silvers and 15 yellows while in control jar 2 there were 8 dark green, 23 light green and 18 silver lemons. In jar 3, which was placed under mold emanations on August 26, pronounced shedding of "buttons" was noticed on September 14. These symptoms indicate marked shortening in storage life of fruit exposed to emanations of *Penicillium digitatum.*

Effects of Fungal Emanations on Different Color Grades of Lemons:—In California lemons are picked according to size, and color separation is carried out in the packing house after washing. This classification is an aid in distinguishing between fruit of different storage properties. The dark green lemons have a storage life of 4 to 6 months, while the fully yellow or "tree ripe" may not keep longer than 4 weeks. The light green and silver are intermediate grades. The grading according to color and the keeping quality vary with district and season. In a number of districts the major portion of the crop is harvested several months ahead of the time when the consumer demand for lemons is greatest. Consequently, a knowledge of the factors that affect the keeping quality of the different grades of fruit is of much interest to the industry.

In experiment 3 an attempt was made to obtain some information on the response of the several color grades of lemons to small concentrations of green mold emanations. The fruit for this experiment came from one orchard in the Upland district, was picked on April

10, washed April 11, and placed the next day at 15 degrees C under a constant air flow of 350 ml/min. The respiration measurements were followed for 4 days prior to differential treatment. On April 17 one jar in each color grade was connected to a container holding a lemon inoculated with green mold. The degree of response to active emanations might be judged by comparing the peak CO_2 values with the respiration rates immediately preceding the introduction of the molds. As calculated from Table I the maximum percentage response was

TABLE I—Effect of Penicillium Digitatum Emanations on Respiration of Lemons at Different Stages of Maturity (In Milligrams Carbon Dioxide Per Kg of Fruit Per Hour)

Maturity	Treatment	Jar No.	April						May		
			17	18	19	21	22	29	5	15	29
Dark green	Mold	16	9.9*	11.3	12.4	16.2	19.8	17.5	16.5	15.8	12.5
	Control	17	11.7	11.7	12.5	11.9	13.0	10.8	10.2	9.6	10.3
Light green	Mold	21	10.3*	13 7	14.4	15.0	18.7	14.4	13.8	13.3	13 3
	Control	22	11.8	12.6	12.1	11.5	12.4	10.4	10.1	9.3	9.6
Silver	Mold	23	11.1*	10.0	14.7	17.2	16.1	15 5	12.1	10.6	10.3
	Control	24	11.7	13.3	13.9	12.8	12.6	9.3	9.0	8.2	8.3
Tree ripe	Mold	25	10.3*	13.2	15.0	12.4	14.0	14.3	10.9	11.7	10 4
	Control	26	11.5	12 3	12.6	12 0	11.5	9.9	8.6	7.2	7.9

*Mold introduced.

100, 82, 55, and 46 for dark green, light green, silver, and tree ripe, respectively. The increase in respiration due to active emanations was markedly higher in the grades with longer keeping quality than in the fully yellow fruit. The latter had the highest incidence of breakdown at the end of the test on June 26. There were 11 lemons in jar 25 affected with Alternaria stem end rot, 6 in jar 23 and none in the rest. This rot is particularly prevalent in fruit of low vitality. At the end of this experiment it was also noticed that the stem ends dropped from the lemons subjected to mold emanations, while they remained firm on the control fruit. It was evident that the keeping quality was materially lowered in all color grades as a result of exposure to active vapors.

Discussion of Results

The maximum quantity of ethylene produced by one lemon fully covered by green mold was found in recent preliminary tests to be approximately 0.9 milliliters per 24 hours. Hence at an air rate of 350 ml/min the sound lemons were subjected to a maximum ethylene concentration of the order of 2 parts per million. The sharp increase in CO_2 production as a result of exposure to mold emanations followed by a decrease resembles the climacteric rise observed in a number of fruits. With lemons there appears to be no well defined climacteric rise in fruit subjected to air at 15 degrees C. In Fig. 2, there is a small rise in CO_2 production toward the end of the storage period which might be considered a climacteric; however, there is evidence against such an interpretation from recently published studies (2) on the effects of oxygen concentration on respiration of lemons. It was

found that under oxygen levels higher than air the climacteric did occur, but only early in storage life when the fruit was changing color from green to yellow. It might be argued that the rates of CO_2 production in air are too low to show a climacteric. But even by the use of the more sensitive pea test (3) no response to etiolated pea seedlings by lemons in air could be observed. Perhaps a method of even higher sensitivity than the triple response of pea seedlings is necessary to produce conclusive results.

The accentuated rates of respiration resulting from exposure to ethylene or mold emanation suggest a possible approach to the question of fruit vitality in lemons. The industry has been interested in a method of ascertaining the probable keeping quality of fruit shortly after harvesting. It appears that the storage life varies materially with fruit of the same color grade but from different districts. Some tests indicate quantitative differences in the behavior of lemons of different vitality, but insufficient data are available for a report at this time.

Summary

Lemons were subjected to emanations of the common green mold (*Penicillium digitatum*) at different times during the storage period. The rates of respiration of the treated fruit samples increased from 60 to 100 per cent over the controls. The response to mold vapors was also marked in the several color grades of lemons.

In all cases the storage life of lemons as indicated by color changes, onset of Alternaria rot, and shedding of stem ends was greatly reduced as a result of exposure to the emanations of the fungus.

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Modified Atmospheres in Relation to the Storage Life of Bartlett Pears

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A year ago the writers reported upon modified atmospheres, (reduced oxygen as well as increased carbon dioxide) in relation to the transportation of deciduous fruits (3). This report presents the effects of somewhat similar atmospheres on Bartlett pears during and subsequent to storage, including five different levels of oxygen and six different combinations of carbon dioxide and oxygen, together with respiration data in the oxygen series of atmospheres. It continues in a more comprehensive manner previous storage work with this fruit (1). The term "storage life" as used in this report refers to the period during which the fruit may be held and subsequently ripen in a normal manner without showing scald, or flesh disorder, and still remain marketable for several days after becoming ripe. It refers to the period of marketability rather than that ending in the cessation of metabolic activity.

Procedure

The fruit used was harvested from the experimental orchards at Davis July 30, 1948 at a stage of maturity considered near the optimum for good storage.[1] After careful sorting and discarding of any injured or badly blemished specimens, 60 pears, or approximately 9,600 grams, were placed in each of a series of wide mouth 5-gallon glass jars. These were fitted with air tight metal covers provided with suitable inlet and outlet tubes for the continuous supply of the desired atmospheres.

After filling, sealing and testing the jars for air leaks they were divided into two groups subsequently spoken of as "carbon dioxide series", and as "oxygen series". In the former carbon dioxide was used at concentrations of 5, 10 and 15 per cent. To half of the jars this gas was added to air, reducing the oxygen concentration to between 18 and 20 per cent. In the other jars containing similar percentages of carbon dioxide, oxygen was reduced to 2½ per cent, by adding nitrogen. The atmospheres in the oxygen series consisted of nitrogen and oxygen only, with the percentage of oxygen at the 1, 2½, 5, 10 and 21 per cent levels. Jars receiving each of the above atmospheres were in duplicate, one of each pair was held at 37 degrees F and the other at 32 degrees F.

The different mixtures of gases were secured from pressure tanks and their flow regulated by flowmeters similar to those described by Claypool and Keefer (4). Separate flowmeter boards were used for each gas in the mixture, hence by combining the proper flow of gas from a flowmeter on each board it was possible to secure any desired mixture and rate of flow. The flowmeters were so adjusted that with

[1]With a color value of 1½ to 2, or a light green on the California Standard Color Chart and an average firmness of 18.5 pounds as measured by a pressure tester having a 5/16 inch plunger point.

the jars full of fruit hourly air changes in the oxygen series stored at 32 degrees F were between 0.42 for the pears in 1 per cent oxygen to 0.60 for those in air. At 37 degrees F the changes were 50 per cent faster. Air changes over the pears in the carbon dioxide atmospheres were the same at both temperatures — from 0.45 changes per hour at the 5 per cent level to 0.30 changes per hour at the 15 per cent level. All of these changes occurred somewhat less frequently each time a portion of the fruit was removed from storage to 65 degrees F for ripening. In no instance, however, were these so infrequent as to permit accumulation of as much as 0.4 per cent of carbon dioxide in any of the jars of the oxygen series.

After allowing 3 days for the pears to come to temperature equilibrium with that of the storage atmosphere, respiration measurements were started. These were initially made at 3- to 5-day intervals; later at 10-day intervals throughout the storage period of the oxygen series, (127 days at 37 degrees F and 159 days at 32 degrees F). Respiration determinations were made by the colorimetric method previously described (4). Such data were not secured on the fruit held in the carbon dioxide atmospheres as neither the above method or any other which has been used is suitable for accurately measuring carbon dioxide respired when fruit is subjected to a continuous flow of a carbon dioxide atmosphere.

Beginning after 6 weeks in the differential atmospheres at 37 degrees F and after 10 weeks at 32 degrees F and at approximately monthly intervals thereafter, a portion of each lot of fruit was withdrawn from the two storage temperatures, observed and placed in air at 65 degrees F for ripening.

Presentation of Results

To avoid using lengthy tabulations of data, an attempt has been made to express color changes in the different atmospheres, as well as some of the respiration results, by a series of graphs or curves. In Figs. 1 to 5 inclusive, increase in color of the different samples[2] in storage is represented by the gradual upward trend of the more horizontal lines. From these at approximately 4-week intervals are drawn the more vertical lines indicating the rapid coloring of the fruit after being withdrawn from storage for ripening in air at 65 degrees F. Finally, after the pears have attained full color and ripeness the short horizontal lines at the top represent the approximate number of days elapsing between full ripe and overripe.

Ripening as Influenced by Carbon Dioxide Atmospheres

The general influence of carbon dioxide atmospheres in retarding ripening is now well known and results of preliminary trials with Bartlett pears, using different proportions of carbon dioxide and of oxygen have been presented previously (1). During the past season,

[2]On account of crowding, the 10 per cent oxygen curve (intermediate between the 5 and 21 per cent) has been omitted from Figs. 3 and 4. The 15 per cent carbon dioxide curves have been omitted from Figs. 1 and 2 for the same reason.

however, additional data were secured whereby different lots of pears held under different carbon dioxide-oxygen concentrations could be compared with comparable lots held in atmospheres of sub-normal oxygen.

In Figs. 1 and 2 comparison is shown between coloring of pears stored in air and in the different carbon dioxide atmospheres. Fig. 1 shows coloring during and subsequent to storage at 37 degrees F; Fig. 2 during and subsequent to 32 degrees F storage. The lines or curves representing the two temperatures are generally similar and are in the same relationship one to the other, except the 5 and the 10

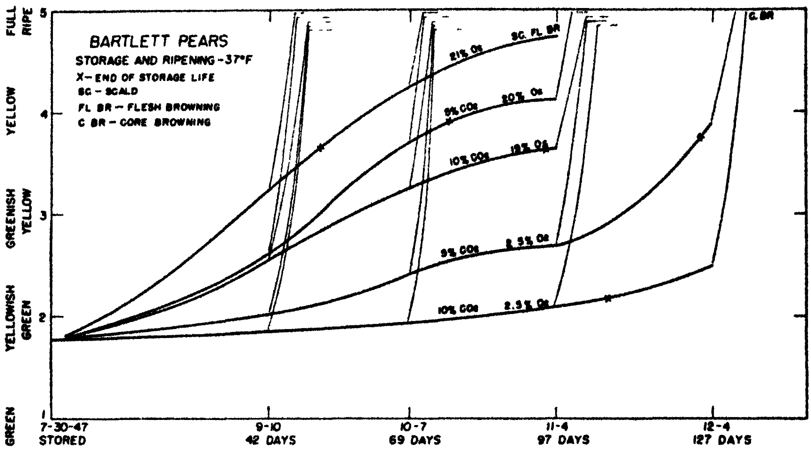

Fig. 1. Influence of carbon dioxide atmospheres upon the storage life of Bartlett pears at 37 degrees F.

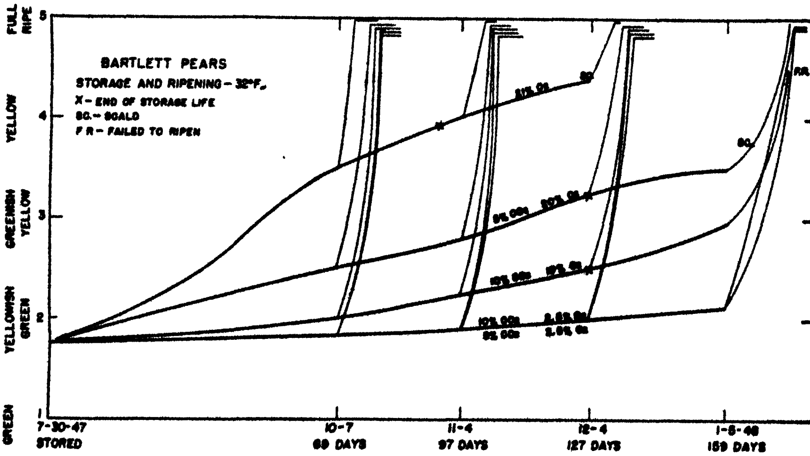

Fig. 2. Influence of carbon dioxide atmospheres upon the storage life of Bartlett pears at 32 degrees F.

per cent carbon dioxide-low oxygen curves at 32 degrees F which are identical. At each temperature these concentrations of carbon dioxide had a definite retarding effect on coloring and prolonged the life of the fruit in storage, and also delayed coloring and softening after removal to 65 degrees F for ripening. At 37 degrees F color retardation was directly related to the carbon dioxide concentration, but at 32 degrees F a 5 per cent concentration was about as effective as either 10 or 15 per cent. In all instances coloring was retarded more when the carbon dioxide was combined with low oxygen than when merely added to air. At the times indicated on Figs. 1 and 2 a portion of each sample of pears was withdrawn from storage and ripened.

Results at 37 Degrees F:—After 42 days or 6 weeks, at 37 degrees F the first lots of pears were removed to air at 65 degrees F for ripening. The fruit which had been stored in air was already advanced somewhat beyond a greenish-yellow color, indicating that it had reached the end of its commercial storage life. When coloring is retarded by carbon dioxide the storage life of the fruit must be judged by its ability to ripen normally after storage. On this basis the addition of 5 to 10 per cent carbon dioxide to air had the same general effect as lowering the air temperature to 32 degrees F. Instead of a storage life of 45 to 50 days, this was extended to 75 to 100 days. In a 15 per cent concentration there was practically no color change in 18 weeks, but flesh injury occurred in the pears held for 14 weeks.

When 5 and 10 per cent carbon dioxide was added to an atmosphere containing only 2½ per cent oxygen the fruit kept for 127 days or 18 weeks. Both lots of fruit ripened normally, and the 5 per cent lot still possessed good dessert quality. Quality of the 10 per cent lot was only fair and some fruits were showing core browning by the time they were ripe. Fifteen per cent carbon dioxide combined with 2½ per cent oxygen again caused some core browning and an off flavor after 14 weeks.

Results at 32 Degrees F:—Bartlett pears in air at 32 degrees F may be kept in good condition for 12 to 14 weeks. Five and 10 per cent carbon dioxide, however, increased their life by more than 40 days, and when it was added to an atmosphere containing only 2½ per cent oxygen, the fruit held 70 days longer than in air and ripened normally with fair dessert quality 159 days or nearly 23 weeks after harvest. On account of injury, 15 per cent carbon dioxide did not increase storage life at 32 degrees F over that of air.

The relative color of the different samples when removed from storage was indicative of the order in which they would attain full color and ripeness in 65 degrees F air. Pears stored in carbon dioxide combined with low oxygen usually required 3 to 4 days longer to become ripe than those stored in air. Ripening of the carbon dioxide-normal oxygen samples was intermediate between the two.

Ripening as Influenced by Sub-Normal Oxygen Atmospheres

Comparable samples of pears to those held in carbon dioxide atmospheres were stored in atmospheres without carbon dioxide, but where

the oxygen levels were maintained at 1, 2½, 5 and 10 per cent. The results obtained from the lower oxygen levels, together with those secured from air, are shown in Figs. 3 and 4. Low oxygen concentration has the same general influence in retarding ripening as does the addition of carbon dioxide. The effectiveness of sub-normal oxygen, however, is not always seen until the concentration is reduced below 10 per cent. Results are more marked at the 5 per cent levels, but it is only when the oxygen is reduced to 2½ per cent, and particularly to the 1 per cent level that ripening is materially retarded and the storage life lengthened.

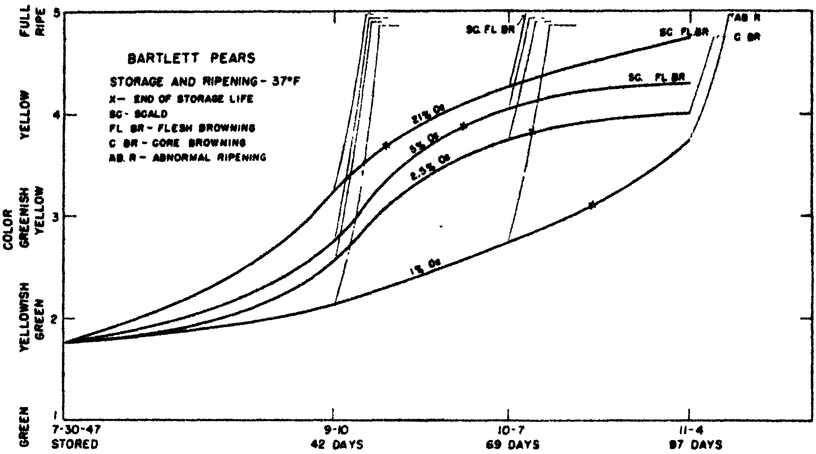

FIG. 3. Influence of sub-normal oxygen atmospheres upon the storage life of Bartlett pears at 37 degrees F.

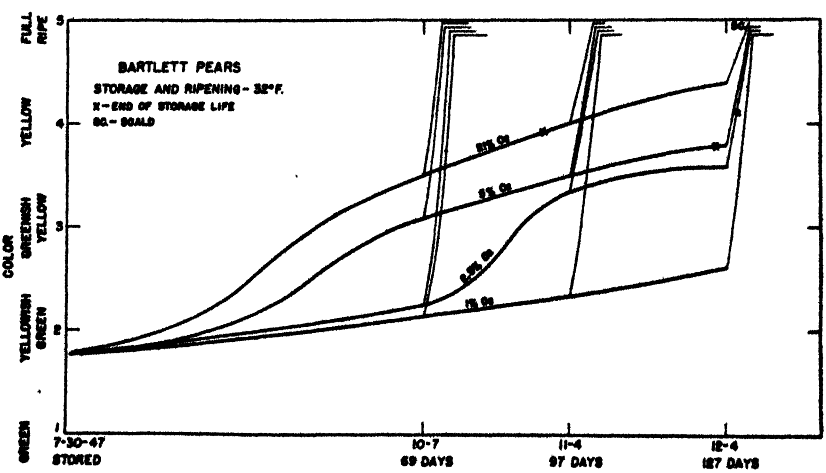

FIG. 4. Influence of sub-normal oxygen atmospheres upon the storage life of Bartlett pears at 32 degrees F.

Naturally, coloring of the different lots was more rapid and the storage period shorter at 37 than at 32 degrees F, but the influence of the oxygen reduction was similar in each.

Results at 37 Degrees F:—Color curves illustrating ripening at 37 degrees F are shown in Fig. 3. At the end of 6 weeks when the first samples were removed from storage, differences in color between the fruit held in air and that in 1 per cent oxygen were striking. The former was decidedly yellowish and already near the end of its commercial life, while the latter was still predominantly green and required several days longer to become ripe. Intermediate between these two lots were the samples held in 2½ and 5 per cent oxygen. The 8 per cent oxygen curve not shown because of crowding, lies between the 5 per cent oxygen and air curves.

At the second withdrawal of samples after 69 days, or 10 weeks, color difference between the air and 1 per cent lots had become still greater. Differences between the pears in air and in 5 per cent oxygen, however, were now less and the two lots were of similar appearance. Pears in 2½ per cent oxygen showed only slightly less color than those held at the 5 per cent level, and both lots had now reached the end of their commercial life. The air sample, still held for comparison, developed scald and breakdown in the flesh before ripening.

These same disorders developed in the 5 per cent oxygen sample during the next 30 days in storage. Pears in the 2½ per cent oxygen atmosphere were still of normal appearance but developed core browning before ripening. The fruit in 1 per cent oxygen had now developed close to a yellow color and had been held beyond the time when able to ripen in a normal manner. The estimated storage life of the pears in 1 per cent oxygen was approximately 80 to 85 days as compared with 45 to 50 days in air.

Results at 32 Degrees F:—The results secured at 32 degrees F are shown in Fig. 4. Although some slight color differences could be observed in the air and in the 5 per cent oxygen sample after 6 weeks, the first inspection and the first fruit removed for ripening from the 32 degrees F temperature was at the end of 10 weeks. For this period of time the 2½ per cent oxygen sample remained practically as green as the 1 per cent sample, but both the air and the 2½ per cent samples had changed from green to greenish-yellow and were similar in appearance to comparable lots after only 6 weeks at 37 degrees F. During the next 30-day period these samples and also the fruit in 1 per cent oxygen showed a gradual increase in color, the actual amount being in relation to the oxygen level. Soon after this first inspection, however, the fruit in 2½ per cent oxygen began to show a noticeable color increase and at the second inspection, after 97 days it had nearly as much color as the 5 per cent oxygen sample. Little color change had occurred in the 1 per cent sample and it was now in striking contrast to the other four. During the final 30 days in storage all lots continued to color slightly. The air sample was now yellow and both it and the 10 per cent oxygen sample showed slight scald by the time the fruit was ripe. No scald developed on the pears in the three lower oxygen concentrations, but those stored in 5 per cent oxygen had reached the

end of their storage life. Little dessert quality remained in either the 5 or the 2½ per cent samples. The quality of the 1 per cent lot was still fair to good, and after the fruit became ripe it remained in marketable condition 4 to 5 days.

From the foregoing observations it has been seen that the most effective atmospheres for retarding coloring and extending storage life have been either 1 per cent oxygen or 2½ per cent oxygen combined with 5 to 10 per cent carbon dioxide. In Fig. 5 are brought together the color curves representing fruit in air, in 1 per cent oxygen, and in 2½ per cent oxygen with 10 per cent carbon dioxide at each of the

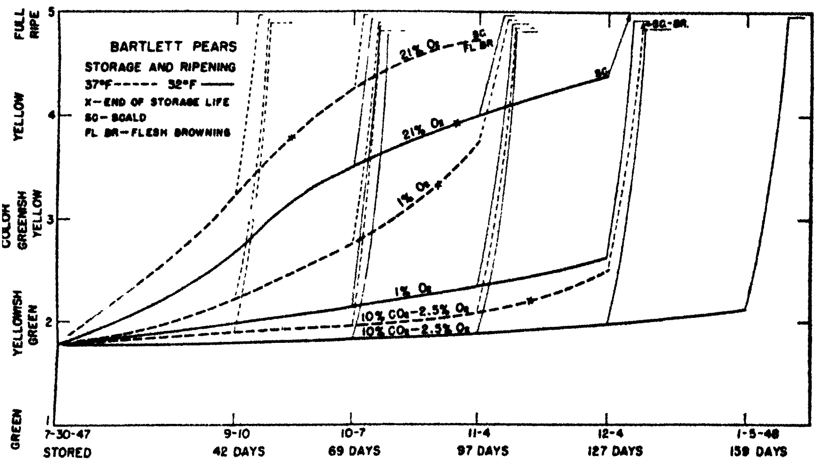

FIG. 5. Storage life of Bartlett pears as influenced by temperature, low oxygen, and a combination of low oxygen and of carbon dioxide.

storage temperatures. At 37 degrees F the 1 per cent oxygen curve occupies an intermediate position between that of air and the 10 per cent CO_2-2½ per cent O_2 curve. The fruit had an intermediate storage life of 80 to 85 days. At 32 degrees F both 1 per cent oxygen and 10 per cent CO_2-2½ per cent O_2 had a marked effect in delaying coloring and in lengthening storage life. The carbon dioxide combination retarded color somewhat more than 1 per cent oxygen and kept the fruit free from any physiological disorder and of fair dessert quality for 159 days. Unfortunately, the 1 per cent oxygen sample was discarded after 127 days. It is believed that it could have been kept in good condition somewhat longer, although in the 1946 tests some slight core browning occurred after 120 days.

Most of the experimental samples were purposely held beyond their normal storage life and injury occurred. Table I shows the approximate length of time the different lots could be held, ripened without injury and marketed.

INFLUENCE OF DIFFERENT OXYGEN LEVELS UPON RESPIRATION

Having observed the results of different oxygen levels upon coloring and ripening it is of interest to see the influence of these upon the

TABLE I—APPROXIMATE STORAGE LIFE OF BARTLETT PEARS IN DIFFERENT ATMOSPHERES .

Atmosphere		Storage Life			
		At 37 Degrees F		At 32 Degrees F	
CO_2	O_2	Days	Approximate Per Cent Increase Over Air	Days	Approximate Per Cent Increase Over Air
		Oxygen Series			
0	1	80-85	73	164*	78
0	2½	70-75	52	127	38
0	5	55-60	20	110	20
0	21	45-50	—	92	—
		Carbon Dioxide—High Oxygen			
5	20	75-90	71	127	38
10	19	95-100	102	127	38
15	18	85	77	85	-8
		Carbon Dioxide—Low Oxygen			
5	2½	120	150	159+	73+
10	2½	105	118	159+	73+
15	2½	85	77	100	8

*Value secured by extrapolation.

general level and trends of respiration (Fig. 6). At both 37 and 32 degrees F respiration rates were directly related to the oxygen level in the atmosphere. The different curves held their same relative position throughout the storage period, except for the 5 and 8 per cent levels which were very close together and crossed and recrossed during the latter part of the period. The respiration rates of all lots were

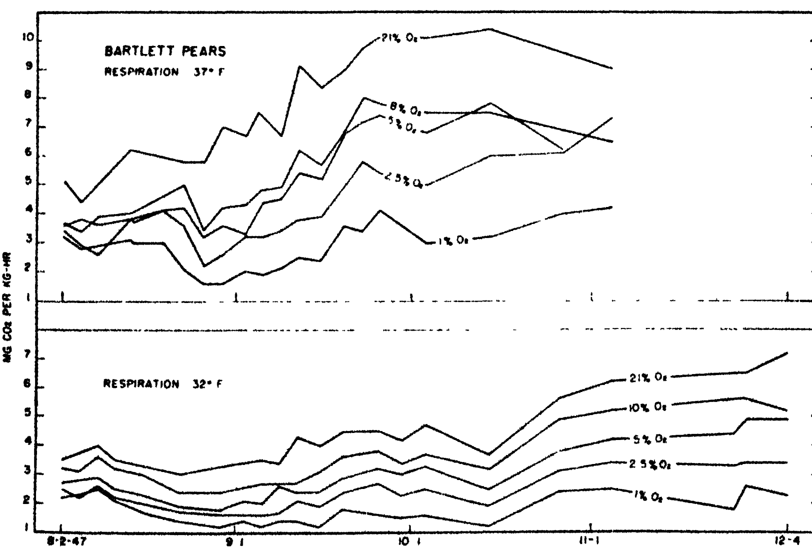

FIG. 6. Respiration rates of Bartlett pears in different sub-normal oxygen levels. Above, at 37 degrees F; below at 32 degrees F.

greater at the end of the experiment than at the beginning, but the increase in the 1 per cent oxygen lot was small. At 37 degrees F there was considerable difference in the shapes of the curves. The air lot after an initial reduction showed an increase in rate which continued until a peak level was reached after 76 days in storage. The 8 per cent oxygen lot moved up only slightly during the first month and reached a peak 3 weeks later. The 5, 2½ and 1 per cent lots all showed some reduction in respiration rate prior to a rise. This was most evident in the 1 per cent lot where this reduced rate continued for about 40 days before it began to increase.

At 32 degrees F respiration curves for the different oxygen levels were closer together and fluctuated less than at 37 degrees F. In all lots there was again a reduction in respiration followed by a subsequent increase. As the oxygen level was reduced, the reduction in respiration was greater and of longer duration. The reduction in air was slight, but at the 1 per cent oxygen level it was reduced nearly 50 per cent for a period of 76 days, and the final respiration rate was almost identical with the initial rate. In the other lots the final rates became increasingly greater as the atmospheric oxygen was increased.

By measuring the area beneath each of the respiration curves with a planimeter, total carbon dioxide respired by each lot of pears throughout the respiration period was obtained. These totals, together with the average hourly rate and the percentage of each to that in air is shown in Table II. When the values for the average hourly respira-

TABLE II—RELATIONSHIP OF CARBON DIOXIDE RESPIRED TO THE OXYGEN LEVEL OF THE ATMOSPHERE

Per Cent O_2 in Atmosphere	Total Mg CO_2 Per Kg of Fruit		Average Mg CO_2 Per Kg Hr		Percentage CO_2 Respired at Different Oxygen Levels	
	In 94 Days at 37 Degrees F	In 124 Days at 32 Degrees F	At 37 Degrees F	At 32 Degrees F	At 37 Degrees F	At 32 Degrees F
1	6,702	5,389	2.97	1.81	36.4	38.6
2½	10,213	7,460	4.53	2.51	55.5	53.5
5	12,709	9,400	5.63	3.16	69.0	76.4
8	13,259	—	5.88	—	72.0	—
10	—	11,554	—	3.88	—	82.8
21	18,418	13,949	8.16	4.69	100.0	100.0

tion rates are plotted against the per cent oxygen in the atmosphere they form very regular curves, except for the 8 per cent value at 37 degrees F which is somewhat low (Fig. 7). The curves indicate that within the range studied the reduction in respiration rate per increment of oxygen is much greater in the low oxygen portion of the curves than at the higher levels. This was true at both 37 and 32 de-degrees F, although the curve at 32 degrees F is somewhat flatter due to the greater reduction of the respiration rate, resulting from the lower temperature.

The influence of temperature may best be seen by measuring the total output of carbon dioxide at 37 and 32 degrees F for the same period of time, 94 days. When this comparison is made it will be noted from Table III that an increase of 5 degrees in temperature resulted

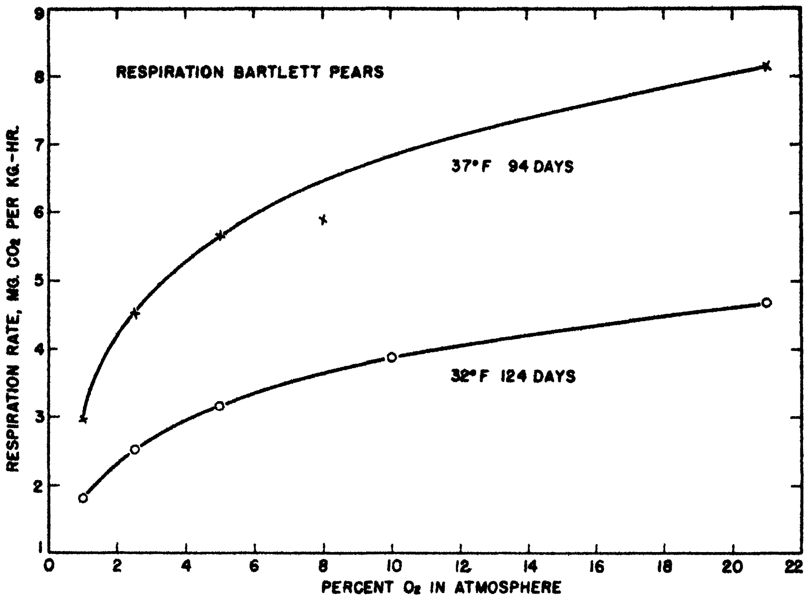

FIG. 7. Respiration rate of Bartlett pears plotted against the oxygen level of the atmosphere.

TABLE III—RATIO OF CARBON DIOXIDE RESPIRED FROM BARTLETT PEARS AT 37 DEGREES F TO THAT AT 32 DEGREES F DURING A PERIOD OF 94 DAYS AT DIFFERENT OXYGEN LEVELS

Per Cent O_2 in Atmosphere	Total Mg of Carbon Dioxide		Ratio 37 to 32 Degrees F
	At 37 Degrees F	At 32 Degrees F	
1	6.702	3.817	1.76:1
2½	10.213	5.050	2.02:1
5	12.709	6.216	2.04:1
8	13.259	——	——
10	——	7.662	——
21	18.418	9.295	1.98:1

in doubling the respiration rate of all but the 1 per cent oxygen level where the ratio was 1.75 to 1. From these results it would be expected that the storage life of the fruit at 32 degrees F would be approximately double that at 37 degrees F and reference to the estimated life at the two temperatures as given in Table I shows a fairly good correlation.

As a part of their storage work with apples, Kidd and West (5) calculated the total amount of carbon dioxide respired by Bramley Seedling apples between the time of picking and fungal breakdown, and found the total to be reasonably constant at each of three different temperatures. Smock (6) in several trials with McIntosh apples held in air and in controlled atmospheres for the period of their marketability, rather than to complete breakdown, also found the cumulative values of carbon dioxide to be approximately constant in the different

treatments. He stated, however, that some variation occurred in different years and that the results may be affected by secondary factors such as rotting, scald and internal disorders. Biale (2), working with avocadoes secured similar results to those for apples, but like Smock, states the data are still insufficient to recommend cumulative carbon dioxide production as a storage criterion. Our work in this regard with Bartlett pears was likewise too limited for the results to be conclusive, but they do closely conform to those of Smock and Biale.

The commercial storage life of Bartlett pears has been estimated at 45 to 50 days at 37 degrees F and 84 to 90 days at 32 degrees F. After 49 days in air at 37 degrees F and 84 days at 32 degrees F the experimental lots had respired 7,752 and 7,889 Mg CO_2 per kg of fruit, respectively. Noting this similarity in the total respiration of these air samples, comparison was made of those in sub-normal oxygen atmospheres to determine if they too, after respiring similar amounts of carbon dioxide would be approaching the end of their storage life.

The results are shown in Table IV and Fig. 8. Except for the two values in 1 per cent oxygen which were obtained by extrapolation, the number of days required for each sample to respire a similar quantity of carbon dioxide to that evolved from the air samples does coincide rather closely with the estimated storage life given in Table I. If these

TABLE IV—DAYS REQUIRED FOR BARTLETT PEARS HELD AT DIFFERENT OXYGEN LEVELS TO RESPIRE EQUIVALENT AMOUNTS OF CARBON DIOXIDE

Per Cent O_2 in Atmosphere	Total Mg CO_2 Per Kg of Pears			
	At 37 Degrees F		At 32 Degrees F	
	Amount	Days	Amount	Days
1	7,782	104*	7,800	164**
2½	7,798	78	7,880	129
5	7,841	66	7,844	110
10	—	—	7,913	96
21	7,752	49	7,889	84

*Last 10 days by extrapolation.
**Last 37 days by extrapolation.

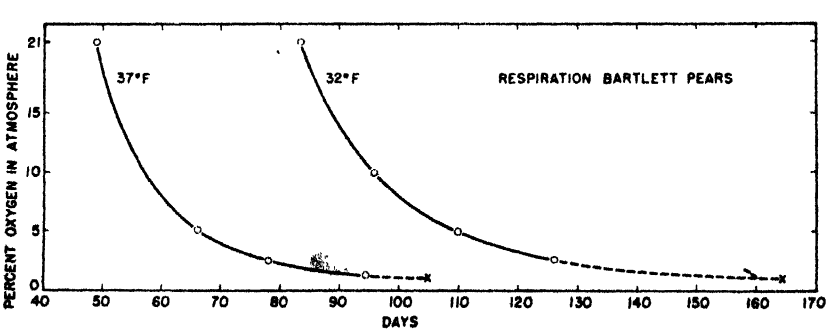

FIG. 8. Time plotted against oxygen level in the atmosphere for the evolution of given amounts of carbon dioxide, representing the approximate storage life in air.

results can be confirmed by additional data then cumulative carbon dioxide may become an index for storage life, and by means of curves such as shown in Fig. 8, the life of pears in different atmospheres and at different temperatures may be readily estimated.

Summary

Observations were made on the ripening of Bartlett pears during and following storage at 32 and at 37 degrees F. The fruit was held (a) in a series of oxygen atmospheres in which the normal oxygen of the air was reduced by the addition of various percentages of nitrogen, and (b) in two series of carbon dioxide atmospheres — one where the oxygen was diluted according to the percentage of carbon dioxide added, and the other in which all the atmospheres contained 2½ per cent of oxygen but with different percentages of both carbon dioxide and of nitrogen. Respiration determinations were made of the fruit held in the sub-normal oxygen atmospheres to which no carbon dioxide was added.

Reduction of oxygen to 2½ and to 1 per cent materially delayed coloring and ripening, and compared with air, 1 per cent oxygen increased storage life approximately 75 per cent at both 37 and at 32 degrees F. In an atmosphere containing 5 per cent oxygen, coloring and ripening were delayed slightly, and at the 10 per cent level results were similar to those secured in air.

Results from adding carbon dioxide to air and from combining it with low oxygen confirmed previous observations. Color retardation was directly related to the carbon dioxide level, except when combined with low (2½ per cent) oxygen at 32 degrees F where a 5 per cent concentration was about as effective as greater concentrations. At both 32 and 37 degrees F coloring was retarded more when the carbon dioxide was combined with 2½ per cent oxygen than when added to air.

Due to injurious effects shown by Bartlett pears stored in carbon dioxide atmospheres, the length of storage life does not necessarily coincide with the retention of color. Fifteen per cent of carbon dioxide practically "fixed" color for 5 or 6 months, but the period during which the flesh of the fruit remained normal and subsequently ripened satisfactorily was materially less than that of fruit stored in 5 or 10 per cent levels. Moreover, the latter concentration proved superior to the former only when the carbon dioxide was added to normal oxygen (air) and the fruit stored at 37 degrees F.

At 32 degrees F pears held in 5 or 10 per cent carbon dioxide added to air and those held in 1 per cent oxygen kept equally well, but at 37 degrees F 10 per cent carbon dioxide was the more effective. When carbon dioxide was combined with only 2½ per cent oxygen the results were more marked than either when it was combined with air or when 1 per cent oxygen was used alone. In an atmosphere of 5 to 10 per cent carbon dioxide and 2½ per cent oxygen, pears at 32 degrees F remained in good condition and ripened satisfactorily after nearly 6 months or almost twice the usual storage period.

Both carbon dioxide and low oxygen atmospheres had a residual effect upon ripening of the fruit after it was removed to a temperature of 65 degrees F, most samples requiring several days longer to ripen than the corresponding samples held in air. After becoming fully ripe there was usually little difference in the time each remained marketable.

Carbon dioxide evolved from the pears stored in sub-normal oxygen atmospheres was directly related to the oxygen level. After an initial reduction in the respiration rate, lasting from only a few days in the air sample stored at 37 degrees F to over 10 weeks in the 1 per cent oxygen sample at 32 degrees F, the rates increased toward, or to the climacteric peak. The respiration level for all lots of fruit was thus greater at the end of the storage period than at the beginning, although the increase in the 1 per cent oxygen lots was small.

Increasing the storage temperature from 32 to 37 degrees F resulted in a 75 to 100 per cent increase in respiration rates, and a reduction in storage life of approximately 50 per cent.

Measurements of cumulative carbon dioxide respired by Bartlett pears stored in different sub-normal oxygen atmospheres supported the limited results of others indicating that when fruit in different atmospheres has respired an equal amount of carbon dioxide each has reached a comparable stage of its storage life.

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An Air Purification Trial in a Wenatchee Apple Storage

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It has been shown by Smock (2, 3) that under certain conditions the gases evolved by one lot of apples will stimulate the ripening of a second lot in storage. Smock and Southwick (4) found that air purification with activated coconut shell carbon added a month or slightly more to the storage life of Wealthy, Cortland and McIntosh apples from the standpoint of fruit firmness. Studies by Munkelt (1) suggested that activated carbon made from coconut shell had unusually high adsorptive capacity.

Uota and Smock (6) found that ozone did not appreciably lower the volatile level in storage chambers and that activated carbon was the most effective means tried for removing odors and volatiles. This study was conducted to check the response of 10 varieties of western grown apples when activated coconut shell carbon was used to filter the air in a large commercial cold storage.

Methods

A 40,000 box room equipped with diffuser and ducts was used for the air purification chamber. Two checks were available, one room of similar capacity but direct expansion pipe cooling, and another separate storage of several hundred thousand boxes with central blower system with reverse flow type air distribution. Five hundred and fifty pounds of activated coconut shell carbon 6 to 14 mesh was spread on nine trays 4 feet by 6 feet. The layer of carbon was ¾ inches deep on each tray. Cross pieces at 1-foot intervals supported the window screen bottoms of the trays on which the carbon rested. The trays were arranged at 6 inch intervals one above the other and a sheet of galvanized steel was placed under each tray in such a way that suction brought the storage air down through one tray of carbon and then through the blower and back to the room. An auxiliary centrifugal blower of 6000 cfm capacity was used to draw the air through the carbon and deliver it to the suction side of the diffuser. Both the air purification unit and the cooler diffuser were operated continuously throughout the storage season. A volume of air equal to the air space in the room passed through the carbon each 15 minutes. Good air distribution in the room from ducts maintained a movement of between 30 to 35 linear feet past the boxes of fruit where it was properly stacked. Smock, Kayan, and Francis (5) have pointed out that this rate of movement is sufficient to prevent building up of volatiles in the stacks, although a higher rate of air flow may be advantageous during the cooling period.

Ten varieties of apples, Winesap, Golden Delicious, Richared Delicious, Starking Delicious, Common Delicious, Rome Beauty, Red Rome Beauty, McIntosh, Yellow Newtown and Jonathan were harvested at the Tree Fruit Experiment Station, Wenatchee at several different harvest dates ranging both before and after commercial

harvest for each variety. Approximately 10 boxes were harvested at each picking from each variety and composite boxes of the fruit were placed in each storage room. An additional lot was wrapped with oiled paper and placed in a check storage without air purification.

A core temperature of 32 degrees F was the goal in each storage and was achieved in the air purified room and the large reverse flow check storage, but the 40,000 bushel check storage room ranged 2 to 4 degrees higher during the first 3 months of the storage season, due to its use as a segregation and loading room. Relative humidity of 85 to 90 per cent was maintained in all rooms for the greatest part of the season and the fruit did not shrivel appreciably.

At harvest and at times of inspection during the storage season data on the following points were taken. Ground color as indicated by a United States Department of Agriculture color chart; fruit firmness as determined by a Magness-Taylor fruit tester using about 30 presses on a 10-apple sample; soluble solids with a Bausch and Lomb refractometer; composite samples of juice were extracted and frozen for soluble pectin analysis; scald estimations were made at time of removal from storage and after a lapse of a few days with the samples at warm laboratory temperatures of 72 degrees F; the samples were also appraised for general eating quality and any possible cross contamination of storage odors.

Results

Firmness Test: — In the air purified room where 1 pound of activated coconut shell carbon was used for each 80 bushels of stored fruit and where the air was drawn through the carbon four times each hour, a marked retention of firmness was noted on the lots in that chamber. A temperature of 32 degrees F was maintained in this room as well as check room No. 2, but in check room No. 1 the temperature averaged 2 to 4 degrees above 32 degrees F, and therefore was of no value as a check. When the results of all varieties in each treatment were averaged it was found that air purification added at least 3 weeks to the storage life of the apples and in the case of most of the varieties considerably more. With McIntosh only 3 weeks were added to the storage life as evidenced by greater firmness, but all lots except the first harvest were overmature.

With Golden Delicious, Winesap, Rome Beauty, and Red Rome considerably more than a month was added to the storage life on the basis of firmness, but with Richared Delicious, Common Delicious, Starking Delicious, Yellow Newtown and Jonathan considerably more extension of storage life was observed on the basis of firmness. Comparative data on firmness are shown in Table I. The firmness in pounds pressure of all lots before and after storage is presented. Smock (4) points out that time added to the storage life by a treatment can be approximated by plotting on a graph the pressure at harvest on the ordinate and the days in storage on the abscissa. The additional time required for the treated fruit to become as soft as the checks is an approximation of the added storage life. It is assumed that pressure losses are regular and follow a straight line or nearly so.

TABLE I—THE EFFECT OF AIR PURIFICATION ON THE RETENTION OF FIRMNESS OF TEN VARIETIES OF APPLES, EACH OF WHICH WAS HARVESTED AT FOUR DIFFERENT HARVESTING DATES

Harvest Date	Firmness (Pounds)	Inspection After Storage (Apr 3, 1948) Check (Pounds)	Air Purification (Pounds)
	Winesap		
Sep 9	21.7	15.0	18.3
Sep 19	19.8	15.3	18.4
Sep 27	22.0	15.0	16.9
Oct 18	20.6	16.3	17.2
Average	21.03	15.4	17.7
	Golden Delicious		
Sep 2	19.8	11.9	15.7
Sep 9	19.4	11.3	12.7
Sep 19	16.6	12.1	12.5
Sep 27	18.1	11.7	12.9
Average	18.5	11.8	13.5
	Richared		
Sep 2	18.3	14.7	15.1
Sep 9	17.5	13.7	17.3
Sep 19	19.2	14.5	17.9
Sep 27	19.0	14.2	16.6
Average	18.5	14.3	16.7
	Common Delicious		
Sep 2	18.2	14.4	17.9
Sep 9	17.6	14.0	16.2
Sep 19	17.0	13.3	14.8
Sep 27	21.2	12.2	14.6
Average	18.5	13.5	15.9
	Starking Delicious		
Sep 2	17.9	15.4	16.4
Sep 9	16.9	14.7	15.5
Sep 19	18.8	14.2	17.2
Sep 27	18.5	14.7	17.4
Average	18.0	14.8	16.6
	Rome Beauty		
Sep 9	20.9	12.9	15.1
Sep 19	20.8	14.0	16.2
Sep 27	20.4	13.0	14.7
Oct 18	21.7	12.1	13.8
Average	20.9	13.0	14.9
	Red Rome		
Sep 2	20.6	13.7	16.5
Sep 9	22.8	13.6	14.5
Sep 19	23.0	12.3	14.4
Sep 27	20.5	12.0	14.4
Average	21.7	12.9	14.9
	Yellow Newtown		
Sep 9	23.0	15.4	17.7
Sep 19	20.3	16.2	20.1
Sep 27	19.7	15.5	18.9
Oct 18	18.8	15.1	18.1
Average	20.5	15.5	18.7
	Jonathan		
Sep 2	17.8	12.2	16.7
Sep 9	16.9	10.4	13.5
Sep 19	16.0	10.5	11.9
Sep 27	17.4	10.3	12.4
Average	17.0	10.8	13.6
	McIntosh		
Sep 2	21.9	9.7	15.3
Sep 9	16.6	10.8	11.3
Sep 19	15.8	13.8	14.0
Sep 27	11.5	8.7	10.7
Average	16.5	12.6	12.8

TABLE II—Storage Scald Development at 32 Degrees F as Effected by Variety of Apple Date of Harvest and Storage Treatment (Out of Storage April 3, 1948)

Harvest Date (1947)	Check (Per Cent)	Oiled Paper Wraps (Per Cent)	Air Purification (Per Cent)
	Golden Delicious		
Sep 2	76	57	0
Sep 9	0	9.5	0
Sep 19	0	0	0
Sep 27	0	0	0
Oct 19	0	0	0
	Richared Delicious		
Sep 2	100	100	100
Sep 9	54	64	50
Sep 19	0	0	0
Sep 27	0	0	0
	Starking Delicious		
Sep 2	100	100	25
Sep 9	100	100	26
Sep 19	0	0	0
Sep 27	0	0	0
	Common Delicious		
Sep 2	100	100	100
Sep 9	50	4	48
Sep 19	0	0	0
Sep 27	0	0	0
	Red Rome		
Sep 2	65	95	36
Sep 9	80	72	38
Sep 19	15	11	10
Sep 27	25	0	0
	McIntosh		
Sep 2	0	0	0
Sep 9	0	0	0
Sep 19	0	0	0
Sep 27	0	0	0
	Jonathan		
Sep 2	47	0	0
Sep 9	0	0	13
Sep 19	0	0	0
Sep 27	0	0	0
	Yellow Newtown		
Sep 2	0	0	0
Sep 9	5	0	0
Sep 19	0	0	0
Sep 28	10	0	0
Oct 18	0	0	0
	Rome Beauty		
Sep 2	100	100	100
Sep 9	100	86	100
Sep 19	37	0	38
Sep 27	59	0	41
Oct 18	16	0	0
Nov 17	0	0	0
	Winesap		
Sep 2	87	65	72
Sep 9	0	0	0
Sep 19	0	0	0
Sep 27	0	0	0
Oct 18	0	0	0

TABLE III—Soluble Solids as Affected by Variety, Maturity and Storage Treatment (Out of Storage April 3, 1948)

Harvest Time (1947)	Oiled Paper Wraps (Per Cent)	Check (Per Cent)	Air Purification (Per Cent)
	Golden Delicious		
Sep 2	13.5	15.2	14.3
Sep 9	14.2	15.0	15.5
Sep 19	13.9	15.2	14.5
Sep 27	13.8	14.2	13.5
Oct 18	14.6	14.7	15.2
	Yellow Newtown		
Sep 2	10.1	12.0	11.4
Sep 9	11.7	12.7	12.8
Sep 19	12.2	12.8	13.6
Sep 27	12.2	14.2	13.6
Oct 18	14.0	14.1	14.0
	Jonathan		
Sep 2	15.5	13.9	14.5
Sep 9	14 7	13.2	13.3
Sep 19	13.6	13.4	13.2
Sep 27	14.2	14.4	13.4
	Rome Beauty		
Sep 2	11.4	12.1	11.9
Sep 9	12.4	12.2	13.1
Sep 19	14.8	14.2	14.0
Sep 27	12.1	12.9	12.2
Oct 18	14.5	12.4	13.2
	Red Rome		
Sep 2	12.9	13.8	13.5
Sep 9	13.0	13.2	13.2
Sep 19	13.5	12.2	12.5
Sep 27	13.2	12.6	14.4
	Winesap		
Sep 2	10.2	13.0	13.9
Sep 9	12.4	13.7	13.4
Sep 19	14.0	13.8	15.8
Sep 27	13.0	14.3	14.7
Oct 18	14.0	14.5	14.3
	McIntosh		
Sep 2	10.1	13.1	13.5
Sep 9	15.0	13.4	14.2
Sep 19	14.0	13.8	14.0
Sep 27	14.6	13.6	14.0
	Richared Delicious		
Sep 2	11.7	12.5	13.1
Sep 9	12.1	13.9	14.2
Sep 19	16.4	13.9	14.8
Sep 27	14.0	14.6	13.4
	Starking Delicious		
Sep 2	9.6	13.5	12.3
Sep 9	12.8	13.8	14.8
Sep 19	13.5	12.4	12.2
Sep 27	13.5	13.2	13.2
	Common Delicious		
Sep 2	11.0	13.0	13.5
Sep 9	13.9	13.5	13.3
Sep 19	14.7	14.2	13.7
Sep 27	13.8	13.6	13.7

TABLE IV—Ground Color as Effected by Storage Treatment (Inspected April 3, 1948)

At Harvest	Oiled Paper Wraps	Check	Air Purification
	Golden Delicious		
Sep 2	3.0	4.0	3.5
Sep 9	3.4	4.0	3.7
Sep 19	3.5	4.0	3.8
Sep 27	3.5	4.0	3.5
Ocr 18	4.0	4.0	4.0
	Yellow Newtown		
Sep 2	1.0	1.8	1.3
Sep 9	1.0	2.0	1.2
Sep 19	1.5	2.5	2.0
Sep 27	1.5	2.0	2.0
Oct 18	2.3	4.0	3.0
	Jonathan		
Sep 2	2.5	2.8	2.6
Sep 9	2.6	2.8	2.7
Sep 19	2.5	3.5	2.5
Sep 27	2.7	3.0	2.8
	Rome Beauty		
Sep 2	2.0	2.5	2.0
Sep 9	2.0	2.5	2.3
Sep 19	2.0	2.5	2.2
Sep 27	2.2	2.5	2.5
Oct 18	3 0	3 5	3.5
	Red Rome		
Sep 2	3.0	3.2	3.0
Sep 9*	2.0	2 3	2.0
Sep 19	2.5	2.5	2.5
Sep 27	2.4	2.6	2.5
	Winesap		
Sep 2	2 0	3.0	3.0
Sep 9	2.0	3.0	3.0
Sep 19	2.0	3.0	2.5
Sep 27	2.5	3.0	3.0
Oct 18	3.0	4.0	3.2
	McIntosh		
Sep 2	1.0	2.0	2.0
Sep 9	2.5	3.0	3.0
Sep 19	3.5	4.0	4.0
Sep 27	4.0	4.0	4.0
	Richared Delicious		
Sep 2	2 0	3.5	3.0
Sep 9	2.5	3.0	3.0
Sep 19	3.0	4.0	4.0
Sep 27	3.7	4.0	4.0
	Starking Delicious		
Sep 2	2.5	3.0	3.0
Sep 9	3.0	4.0	4.0
Sep 19	4.0	4.0	4.0
Sep 27	4.0	4.0	4.0
	Delicious		
Sep 2	2.0	3.0	3.0
Sep 9	2.5	3.5	3.0
Sep 19	2.5	3.5	2.5
Sep 27	2.6	4.0	3.0

*Red Romes from another tree were used or this and the remaining sample

Smock and Southwick (4) find that this type approximation of "days storage life added" seems a conservative method of evaluating a treatment.

As shown in Table II there is a marked difference in susceptibility to storage scald with the different varieties tested. Scald was most severe with early harvested Romes, Red Romes, Common Delicious, Starking and Richared and less severe with Golden Delicious, Winesap, Jonathan with no scald showing on such varieties as McIntosh and Yellow Newtown.

With Starking Delicious and Golden Delicious, the air purification seemed to give slightly more protection against scald than did the oiled paper wraps, the same was true for Red Rome, but not for Rome Beauty, Winesap, Common Delicious and Richared Delicious. It would be helpful if the threshold level for scald induction by total volatiles in the storage air could be determined for each variety, but as yet no information is available on this point.

In Table III are shown the soluble solids in the various lots. The data from the juice of these 10 apple composit samples does not seem to give any significant correlation and seems to have little value as an index of current maturity.

Examination of the ground color at harvest and after the storage season with standard United States Department of Agriculture color chart showed a fairly consistent tendency for the lots in air purification to lose their green ground color more slowly.

Summary

Air purification with activated coconut shell carbon added on the average about a month or more to the storage life of the apples. With varieties like the strains of Delicious and Jonathan considerably more than a month was added to the storage life from the standpoint of fruit firmness.

As optimum maturity for best storage is approached, there is a marked reduction in the tendency for most varieties of apples to develop storage scald. Under the conditions of the test, air purification provided about the same degree of protection from scald as did oiled paper wraps.

Some slowing down of the ground color change of the apples was noted in most of the lots in air purified storages.

The per cent soluble pectin as indicated in exploratory analysis of samples indicates a lower percentage in the lots under air purification, but analysis of all samples was not possible in time for the report.

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Seasonal Incidence of Perfect and Staminate Olive Flowers

By Reid M. Brooks, *University of California, Davis, Calif.*

Irregular bearing is an important and a well-known factor in the production of olives in California; crops from year to year in any one orchard vary from heavy to light, or they may be light for several years. An examination of the flowers both before and during anthesis for three seasons was made as a portion of this study on irregular bearing. This report is concerned with observations of olive buds and flowers for three consecutive years beginning in 1942, on five varieties — Mission, Manzanillo, Sevillano, Atro-violacea, and Rubra — grown at or near the California Agricultural Experiment Station, Davis. Two general types of data were obtained, one dealing with the relative proportion of the two kinds of flowers, perfect and imperfect, produced by the olive tree, and the other dealing with the blooming habit.

Relative Proportion of Perfect and Staminate Flowers

In perfect flowers both pistils and stamens are present; in imperfect flowers only stamens are present, the pistil being abortive and nonfunctioning (Fig. 1). No purely pistillate flowers were found in any

Fig. 1. Olive flowers at anthesis cut longitudinally to show inner structures. Left, staminate flower showing aborted pistil. Right, perfect flower showing normal pistil with its plumose stigma. (Photograph by L. K. Mann)

of the observations. Based on the horticultural varieties examined, the species (*Olea europaea* L.) is andropolygamous. As far as possible, flower buds (Fig. 2) were examined instead of flowers for the following reasons: (a) Some buds that are going to fall from the inflorescence, may do so just before petals expand. Hence, in order to observe in all flowers whether the type was perfect or staminate, the examination was made while the bud was on the inflorescence. (b) In all instances, the examination of buds could be made much more rapidly (because of the ease by which sepals and petals could be removed) than that of flowers — an important factor when large numbers were observed, as in 1944.

Entire branches bearing inflorescences were collected from each tree under observation and brought to the laboratory for examination. All

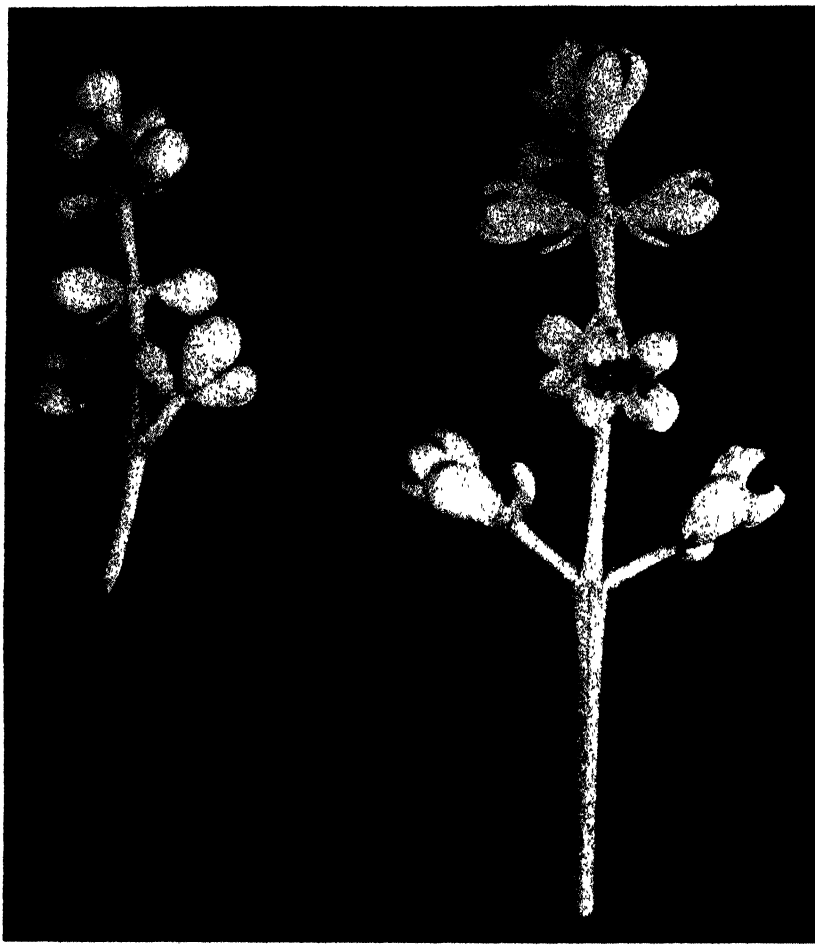

FIG. 2. Olive inflorescences. Left, flower bud stage at which most of the observations were made. Right, inflorescence with flowers at or approaching anthesis. (Photograph by J. R. King)

the flower buds (or flowers) of each inflorescence on each branch were observed, so that if any peculiar situation was present it would lend itself more easily to immediate detection. An attempt was made when collecting the branches (some 12 to 15 around the tree) to secure sufficient inflorescences to make each sample run around 3,000 flowers.

The following bases were used in order to determine the character of the flower. In staminate flowers, the pistil is rudimentary, being barely raised above the floor of the floral tube. The style is exceedingly small and is either brown, a pale greenish white, or white; these same colors obtain in the pistil. The stigma is not at all plumose as is so

characteristic of a normal and functioning one. In a few instances the pistil was some larger before it aborted, but it had the same general appearance and color as did the rudimentary very small aborted pistils. Normal pistils in perfect flowers are large, almost filling the entire space within the unexpanded floral tube; their color is a fresh light green in the bud, turning to a deep green at anthesis; the bifurcate stigma is large and plumose.

1942 Observations:—Flower buds and flowers were checked May 26, 28, June 1 and 2 on each of the six varieties noted above; 18,215 specimens were examined, with the results given in Table I. It may be

TABLE I—OLIVE FLOWER TYPES OBSERVED IN 1942 AT DAVIS, CALIFORNIA

Variety	Date of Observation	Perfect Flower Type		Staminate Flower Type	
		No.	Per Cent	No.	Per Cent
Mission	May 26	246	81.2	57	18.8
	May 28	1,601	66.0	823	34.0
Totals and averages for Mission		1,847	67.7	880	32.3
Manzillo	May 26	304	66.2	155	33.8
Sevillano	May 28	1,348	50 9	1,302	49.1
Atro-violacea	Jun 2	866	25.1	2,581	74.9
Rubra	Jun 1	2,813	87.9	381	12.1

noted that there is a great deal of variation among the six varieties as to flower type, from 25.1 per cent perfect in Atro-violacea to 87.9 per cent perfect in Rubra. However, in Mission, the most important variety grown in California, perfect flowers predominated (67.7 per cent) over the imperfect staminate type. The same situation is true in the Manzanillo variety — the second important variety commercially; but Sevillano (the third important variety grown) had an equal number of perfect and staminate flowers. Since the tendency was to produce more perfect than imperfect flowers in 1942, it was thought advisable to make further observations the following season. In the major varieties the number of flowers for producing fruit and those for producing pollen were present in sufficient numbers in the varieties examined to produce a good crop of fruit in 1942.

1943 Observations:—In general the data for this year (Table II) show a reversal of the relative amounts of the two flower types. For example, in the Mission variety, if all observations are totaled (31,621) there is but 37.6 per cent of perfect flowers whereas in the previous year 67.7 per cent were perfect. A consideration of these two years would suggest that the relative proportion of flower types tended to alternate. Additional data were secured in 1944 to further check this assumption.

1944 Observations:—The data for this year are limited to the Mission variety — 134,847 buds and flowers were examined. To observe if there was a shift from one flower type to another during the weeks previous to full bloom, collections were made every 2 to 5 days from the same tree. It was thought that pistil abortion might take place during this time which could then be checked macroscopically. It is apparent from Table III that there was no shift in flower type during the time from the first to the last collection on any of the trees.

TABLE II—Olive Flower Types Observed in 1943

Variety	Location* and Tree No.	Date of Observation	Perfect Flower Type		Staminate Flower Type	
			No.	Per Cent	No.	Per Cent
Mission.....	UC Farm 25	May 14	1,011	29.0	2,479	71.0
		May 24	1,250	41.6	1,753	58.4
		May 24	1,281	41.1	1,834	58.9
	Davis	May 14	369	14.0	2,266	86.0
	Wolfskill 2	May 16	1,206	32.3	2,533	67.7
	Wolfskill 5	May 21	1,263	38.5	2,017	61.5
	Wolfskill 6	May 21	389	11.0	3,143	89.0
	Wolfskill 14	May 21	1,502	52.0	1,389	48.0
	Winters	May 16	1,250	36.4	2,181	63.6
	Winter Non-deflorated	May 21	2,379	95.0	126	5.0
Sub-total for Mission....			11,900	37.6	19,721	62.4
Manzanillo...	UC Farm	May 12	879	21.7	3,166	78.3
		May 20	1,044	45.7	1,238	54.3
Sevillano....	UC Farm	May 12	389	10.4	3,358	89.6
	Winters	May 16	90	5.8	1,457	94.2
Atro-violacea	UC Farm	May 22	1,320	38.1	2,142	61.9
Rubra.......	UC Farm	May 25	2,965	67.4	1,432	32.6

*Explanation of location of trees:
UC Farm: California Agricultural Experiment Station, Davis.
Davis: Tree growing in a small orchard on the grounds of a residence in Davis.
Wolfskill: Wolfskill Experimental Orchard, near Winters, 14 miles from Davis.
Winters: Tree growing on a ranch near Wolfskill.
Winters Non-deflorated: Tree growing on another ranch near Wolfskill; see text for explanation of "Non-deflorated".

In order to reduce any error in sampling, most samples were replicated (sample numbers A, B, C in Table III), two or more samples being taken from the same tree at the same time. Again, it is seen that results were not consistent; several samples (for example, the first two samples taken on May 3) varied as much as 26 per cent. These results indicated that there is a great deal of variation from branch to branch; this is borne out in observations at harvest time when this variation is noted still to persist.

Observations were made on the size of the fruit crop but no correlation was found between yield in any one year under observation and the following year's percentage of perfect flowers, or between the percentage of perfect flowers and the crop produced during that season.

In order to check specifically the alternate bearing habit of the Mission variety, half of a tree growing at Winters (14 miles west of Davis) was deflorated in 1942 at full bloom; the other half was left with its full and normal complement of flowers. Samples from these halves are labeled "Deflorated" and "Non-deflorated" in Table IV. During the following season (1943) the deflorated half produced a full crop of flowers and fruit, but the non-deflorated portion was barren; the flowers produced from this deflorated half in 1943 were 95 per cent perfect. In 1944, the entire tree produced a profusion of flowers and fruits. Samples were collected from the previously deflorated and non-deflorated halves, the non-deflorated portion, the half not bearing in 1943, produced on an average for five observations 57.0 per cent perfect flowers. The deflorated half of the tree produced an average of 38.4 per cent perfect flowers over five observations. A tree of the Manzanillo variety growing at Davis was treated in like manner to that of the Mission tree; in every respect it behaved similarly in each and every season.

TABLE III—Mission Olive Flower Types Observed in 1944

Location* and Tree Number	Sample Number	Date of Observation	Perfect Flower Type		Staminate Flower Type	
			No.	Per Cent	No.	Per Cent
Wolfskill 3.....	A	May 3	1,093	54.7	904	45.3
	B	May 3	2,127	80.8	506	19.2
Wolfskill 2.....		May 3	726	29.1	1,767	70.9
Wolfskill 2		May 5	1,537	47.9	1,672	52.1
Wolfskill 3 ...	A	May 5	1,089	41.1	1,563	58.9
	B		1,193	59.2	823	40.8
UC Farm 25 ..	A	May 7	1,299	72.4	495	27.6
	B		587	71.3	236	28.7
Wolfskill 3.....	A	May 8	1,144	44.9	1,401	55.1
	B		1,769	60.4	1,162	39.6
Wolfskill 2 ...		May 8	1,423	52.9	1,269	47.1
UC Farm 25...	A	May 9	1,116	63.6	638	36.4
	B		775	49.5	790	50.5
	C		854	50.2	846	49.7
Wolfskill 3.....	A	May 10	1,274	48.6	1,347	51.4
	B		1,267	49.7	1,282	50.3
	C		1,299	52.4	1,181	47.6
Wolfskill 2 ...	A	May 10	2,678	79.1	708	20.9
	B		2,474	77.5	717	22.5
UC Farm 25..	A	May 11	965	41.5	1,361	58.5
	B		1,491	59.6	1,038	40.4
UC Farm 26.		May 11	609	30.1	1,415	69.9
Wolfskill 3	A	May 12	2,001	71.6	794	28.4
	B		2,007	70.0	861	30.0
Wolfskill 2.. ..		May 12	2,515	78.6	684	21.4
Wolfskill 3.. ..	A	May 15	1,836	62.5	1,103	37.5
	B		1,841	68.2	859	31.8
Wolfskill 2 . .		May 15	2,238	62.0	1,372	38.0
UC Farm 25...	A	May 16	113	51.6	1,065	48.4
	B		1,414	55.8	1,120	44.2
Wolfskill 3 . .	A	May 18	1,337	46.9	1,513	53.1
	B		1,742	61.8	1,078	38.2
Wolfskill 2 . .		May 18	1,779	52.7	1,595	47.3
UC Farm 25 .	A	May 19	1,661	70.4	698	29.6
	B		1,199	49.2	1,239	50.8
UC Farm 26...		May 19	1,154	41.3	1,642	58.7
Wolfskill 3 .	A	May 22	601	27.2	1,610	72.8
	B		631	25.5	1,847	74.5
Wolfskill NH .		May 22	421	16.3	2,163	83.7
UC Farm 25....	A	May 25	730	31.5	1,590	68.5
	B		968	39.3	1,495	60.7
UC Farm 26. .		May 25	1,315	43.9	1,680	56.1
UC Farm 25....	A	May 30	694	28.0	1,786	72.0
	B		567	21.1	2,124	78.9
UC Farm 26....		May 30	1,105	36.8	1,900	63.2
Average totals and percentages			69,186	51.3	65,661	48.7

*Explanation of location of trees:
UC Farm: California Agricultural Experiment Station, Davis.
Davis: Tree growing in a small orchard on the grounds of a residence in Davis.
Wolfskill: Wolfskill Experimental Orchard, near Winters, 14 miles from Davis.
Winters: Tree growing on a ranch near Wolfskill.
Winters Non-deflorated: Tree growing on another ranch near Wolfskill; see text for explanation of "Non-deflorated".

TABLE IV—Mission Olive Flower Types Observed in 1944 From a Tree, One-Half of Which Was Deflorated in 1942

Location at Winters	Date of Observation	Perfect Flower Type		Staminate Flower Type	
		No.	Per Cent	No.	Per Cent
Deflorated....................	May 3	1,054	40.9	1,522	59.1
Non-deflorated...........	May 3	1,051	71.2	425	28.8
Deflorated....................	May 8	563	32.5	1,167	67.5
Non-deflorated...............	May 8	170	16.3	873	83.7
Deflorated....................	May 10	906	35.1	1,676	64.9
Non-deflorated...............	May 10	1,018	81.1	237	18.9
Deflorated....................	May 12	892	36.2	1,575	63.8
Non-deflorated...............	May 12	1,268	54.8	1,047	45.2
Deflorated....................	May 15	1,246	47.5	1,379	52.5
Non-deflorated...............	May 15	1,340	62.0	821	38.0

When all observations on each date and from each tree in each location are totalled, it is noted that the ratio of perfect to staminate flowers is 1 : 1 (69,186 : 65,661, or 51.3 per cent to 48.7 per cent). If observations are grouped according to location of trees (at Davis, Wolfskill, Winters) the ratio is still approximately 1 : 1 (54.1 per cent to 45.9 per cent at Wolfskill; 47.7 per cent to 52.3 per cent at Winters and Davis).

Characteristics of the Blooming Habit

The more vigorous and longer shoots appeared to have more perfect flowers as a general rule. For example, in one collection made May 12, branch number 10 was very vigorous and had 326 perfect flowers (93.6 per cent) out of a total of 348; while the next branch counted was short, had grown but little, the inflorescences were exceedingly close together, and had 81 perfect flowers (72.9 per cent) out of a total of 111. It would appear, then, to the advantage of the orchardist to keep his trees in a vigorous condition.

The order of flowering between the two flower types is unique. On an individual inflorescence perfect flower buds reach a state of anthesis before the staminate buds. In the majority of cases, the flowers are borne in groups of threes on the paniculate inflorescence, and as a general rule it is the center flower that is perfect, thus blooming first. Hence, perfect flowers are to a large degree much more advanced on any given day in maturity than are the staminate ones. Furthermore, inflorescences toward the base of a branch tend to bloom before those that are located toward the tip of the branch. The first flowers to open were located on the south side of the tree, in full sun.

Perfect flowers tend to be produced more in certain specific areas than in others. As concerns an individual inflorescence, there are more perfect flowers at the top than at the base of the inflorescence. Flower type is not correlated to the size of the bud, for the majority of staminate buds are as large and plump as are the perfect kind.

Further Studies on Air Purification in the Apple Storage

By F. W. Southwick[1] and R. M. Smock, *Cornell University, Ithaca, N. Y.*

Air purification in the apple storage is aimed at removal of naturally evolved ethylene, scald gases, and possible foul odors. The details of the method of air purification with activated coconut shell carbon and the results in 19 semi-commercial scale tests have already been described (4). This study was conducted to supply additional information on the possibilities of this technique in apple storage.

One of the questions that was raised as a result of the previous study was why results on scald control were erratic from test to test. One possibility seemed to be that the presence of different varieties or different maturities in a room might make scald control more difficult with air purification. Hence, in this study the test apples in some cases were stored alone (no other varieties in the room) or with other varieties.

To evaluate the usefulness of air purification as a means of reducing scald and checking ripening, comparisons were made in some cases with carbon dioxide treatments (2) and shredded oiled paper (1).

Methods

The details of the methods used may be found in another publication (4). At least 2 bushels of test apples were used in each treatment. All apples used were from the Cornell orchards.

The "air blast" treatment involved placing 2 bushels of Rhode Island Greenings in a "tunnel" through which a blast of air at the rate of 186 cubic feet a minute was blown continuously by a fan. This tunnel was held in the control room (test storage 1, room 1). This treatment should have supplied adequate circulation around the apples to flush away any possible accumulations of volatiles.

Shredded oiled paper was used at the rate of ½ pound per bushel of fruit. The apples treated with oiled paper were held in the control room (test storage 1, room 1).

One lot of Greenings was treated with 25 per cent carbon dioxide for 5 days and a second lot with 50 per cent carbon dioxide for 5 days. Both lots were treated at 40 degrees F. These lots were subsequently held in the control room, also.

Some of the rooms were equipped with four Dorex No. 42 canisters of activated coconut shell carbon per 1,000 bushels and some with eight canisters per 1000 bushels. The former number was considered the most reasonable number to use in previous tests (4).

After the apples were removed from storage in February they were tested for fruit firmness with a Magness-Taylor pressure tester and examined for scald. They were then allowed to stand at room temperature for 3 days and were again examined for scald.

A summary of the experimental set-up appears in Table I.

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Results Test Storage No. 1

This experiment was conducted in the apple storage plant at Cornell University where a number of test rooms are available. For the treatments used in this storage see Table I (storage No. 1, rooms 1, 2, 3, 4, and 5). In rooms 1, 2, and 3 only Rhode Island Greenings were stored. In rooms 4 and 5 mixed varieties were in the test rooms.

TABLE I—Data on Experimental Set-Ups (1947–1948)

Test Storage Number	Room No.	Treatment in Room	Room Size (Cu Ft)	Bu in Room	Varieties in Room	Temperature (Degrees F)	No. Canisters Activated Carbon Per 1,000 Bu	Air Flow Per Canister (CFM)
1	1	Control	650	220	Greenings	36	0	—
1	1	Air blast	650	220	Greenings	36	0	—
1	1	Oiled paper	650	220	Greenings	36	0	—
1	1	25 per cent CO_2 5 days	650	220	Greenings	36	0	—
1	1	50 per cent CO_2 5 days	650	220	Greenings	36	0	—
1	2	Air purification	770	250	Greenings	36	4	30
1	3	Air purification	770	250	Greenings	36	8	30
1	4	Control	864	100	Mixed	33	0	—
1	4	Oiled paper	864	100	Mixed	33	0	—
1	5	Air purification	7,200	3,400	Mixed	36	8	34
2	1	Control	34,000	16,000	Mixed	34	0	—
2	2	Air purification	17,784	8,000	Mixed	34	8	30
3	1	Control	34,000	16,000	Mixed	34	0	—
3	2	Air purification	13,794	5,500	Mixed	34	4	50

Rhode Island Greenings Stored Alone:—The results of this experiment appear in Fig. 1 and Table II. It will be noted in Fig. 1 that air purification with four canisters and eight canisters per 1,000 bushels of apples resulted in firmer fruit after storage than no treatment. There was little if any difference between the use of four and eight canisters per 1000 bushels in this test from the standpoint of fruit firmness. Air purification added about 80 days to the storage life of the fruit. The method of estimating this figure has already been described (4).

The use of an air blast through the fruit had little or no effect on fruit firmness, see Table II.

The fruit treated wtih oiled paper was slightly firmer at the end of the test than that without paper. This has not always been found to be the case, however (4). The carbon dioxide treatments resulted in significantly firmer fruit, but the effect was not as great as with air purification.

From the standpoint of scald control the air blast treatment had no effect. This would indicate that merely circulating volatile laden air around the fruit may not reduce the final amount of scald.

The shredded oiled paper treatment reduced the scald but did not control it. It greatly reduced the severe scald, however.

Air purification with four canisters per 1000 bushels cut the total scald in half and reduced the severe scald. It could not be said that it controlled the scald, however, since there was 46.7 per cent scald after

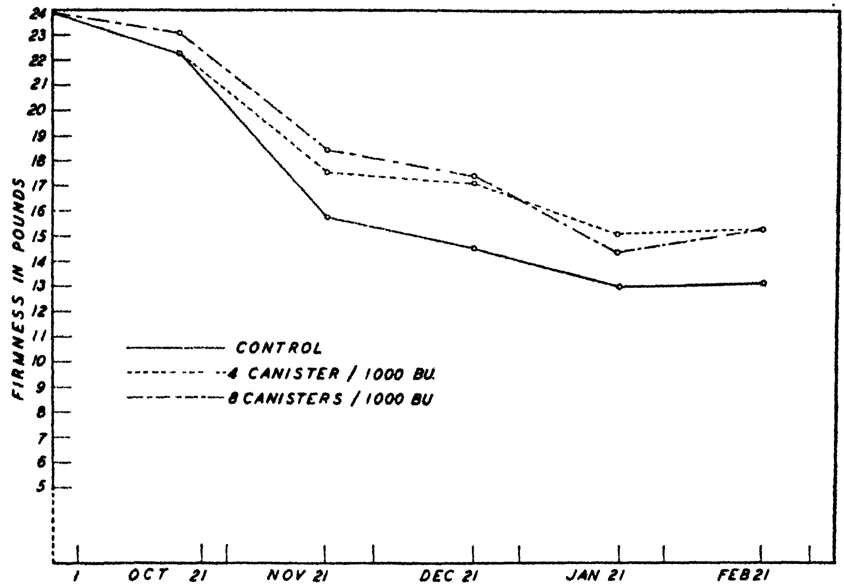

FIG. 1. Changes in fruit firmness in R. I. Greening apples as affected by air purification with four and eight canisters of activated coconut shell carbon per 1000 bushels of fruit at 36 degrees F.

3 days at room temperature. It did a better job of scald control than oiled paper, however.

Air purification with eight canisters per 1000 bushels did not entirely control the scald but did a better job than four canisters. It resulted in about half as much severe and total scald as the use of four canisters.

The use of carbon dioxide treatments did about the same job of scald control as air purification with eight canisters per 1000 bushels. It almost completely controlled the severe scald. The use of 50 per cent carbon dioxide resulted in superficial carbon dioxide injury to the skin. There was also a small amount of internal injury to the flesh. The use of 25 per cent carbon dioxide resulted in almost no injury but in other tests this quantity of carbon dioxide has not been sufficient to always control scald (4).

Rhode Island Greening Stored with Other Varieties:—Air purification at 36 degrees F resulted in slightly firmer fruit than no treatment at 33 degrees F (Table II).

It is noteworthy that the scald was considerably worse in the control room in this test with mixed varieties than it was in the control room with Greenings stored alone. This observation has been made before (3).

Oiled paper did not reduce the scald in this room which presumably had a relatively high volatile level because of the presence of many McIntosh, Northern Spy and other varieties in the room.

TABLE II—EFFECT OF STORAGE TREATMENT ON SCALD AND FIRMNESS OF R. I. GREENING, MCINTOSH AND CORTLAND (STORAGE NO. 1, 1947–1948)

Room No.	Treatment	Varieties in Room	Firmness* (Lbs)	Scald Feb 21, 1948 (Per Cent)			Scald After 3 Days (Per Cent)			External CO_2 Injury (Per Cent)
				Slight	Severe	Total	Slight	Severe	Total	
				Rhode Island Greening						
1	Control	Greenings	13.3	30.98	0.0	30.98	53.95	40.93	94.88	0.0
1	Air blast	Greenings	13.5	30.23	0.0	30.23	57.05	36.47	93.52	0.0
1	Shredded oiled paper	Greenings	13.8	0.0	0.0	0.0	67.10	8.77	75.87	0.0
1	25 per cent CO_2 5 days	Greenings	14.0	0.0	0.0	0.0	14.28	2.30	16.58	1.84
1	50 per cent CO_2 5 days	Greenings	14.4	0.0	0.0	0.0	13.44	0.0	13.44	15.59
2	Activated carbon 4/1000	Greenings	15.4	0.0	0.0	0.0	42.91	3.75	46.66	0.0
3	Activated carbon 8/1000	Greenings	15.5	1.66	0.0	1.66	14.40	1.60	16.00	0.0
4	Control	Mixed	13.4	32.39	22.06	54.45	34.25	63.88	98.13	0.0
4	Shredded oiled paper	Mixed	13.8	63.73	19.78	83.51	12.42	87.57	99.99	0.0
5	Activated carbon 8/1000	Mixed	13.9	19.43	0.0	19.43	53.61	31.91	85.52	0.0
				McIntosh						
4	Control	Mixed	9.4	0.0	0.0	0.0	42.60	6.08	48.68	0.0
5	Activated carbon 8/1000	Mixed	10.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				Cortland						
4	Control	Mixed	11.2	41.73	0.0	41.73	0.0	100.0	100.0	0.0
5	Activated carbon 8/1000	Mixed	11.6	0.0	0.0	0.0	27.39	12.32	39.71	0.0

*Firmness at harvest: R. I. Greenings 23.9 pounds (Sep 25, 1947)
McIntosh 15.2 pounds (Sep 25, 1947)
Cortland 16.0 pounds (Oct 1, 1947)

Air purification in this severe test reduced the scald only slightly but reduced the severe scald by about one-half.

McIntosh in Mixed Variety Storage:—It may be seen in Table II that air purification at 36 degrees F resulted in firmer fruit than similar McIntosh fruit held at 33 degrees F. Air purification entirely controlled the scald on this variety.

Cortland in Mixed Variety Storage:—It will be seen in Table II that air purification at 36 degrees F resulted in firmer Cortland apples than no treatment at 33 degrees F. Air purification did not entirely control scald on this variety but greatly reduced it.

RESULTS TEST STORAGE NO. 2

This experiment was conducted in a privately owned commercial storage with McIntosh. Mixed varieties were in both the control and the air purified room.

McIntosh in Mixed Variety Room:—Table III shows that air purification resulted in fruit that was about 2 pounds firmer than the untreated fruit. Although eight canisters/1000 bushels were used in this test results in the previous year (4) showed about the same effect with four canisters/1000 in the same storage.

TABLE III—EFFECT OF STORAGE TREATMENT ON FIRMNESS OF McINTOSH (STORAGE NO. 2 1947–1948)

Treatment	Varieties in Room	Firmness* (Lbs)
Control	Mixed	9.4
Activated carbon 8/1000	Mixed	11.3

*Firmness at harvest 15.2 pounds (Sep 25, 1947).

RESULTS TEST STORAGE NO. 3

This experiment was conducted in another privately owned commercial storage with McIntosh. Mixed varieties were in both the treated and untreated rooms. In this test only four canisters/1000 bushels were used.

McIntosh in Mixed Variety Storage:—Air purification resulted in fruit at the end of the storage season that was about 1.5 pounds firmer than untreated fruit (Table IV).

TABLE IV—EFFECT OF STORAGE TREATMENT ON FIRMNESS OF McINTOSH (STORAGE NO. 3 1947–1948)

Treatment	Varieties in Room	Firmness* (Lbs)
Control	Mixed	9.4
Activated carbon 4/1000	Mixed	10.9

*Firmness at harvest 15.2 pounds (Sep 25, 1947.)

STORAGE LIFE ADDED AS RESULT OF TREATMENT

Table V includes data on the effect of various fruit treatments on "days storage life added". The method of estimating this figure has already been described (4). Comparisons of Greenings, McIntosh, and Cortland in "mixed variety storage" (in test storage 1) with and without air purification are not made because temperatures were not the same in the test rooms. On the other hand it is obvious in Table II that air purification in mixed variety storage resulted in firmer fruit at 36 degrees F than untreated fruit at 33 degrees F.

It will be noted in Table V that air purification added from a month to over 2 months to the storage life of the fruit from the standpoint of fruit firmness. The use of double the "normal" number of canisters did not significantly increase the value of air purification.

Carbon dioxide treatment and oiled paper also added some to the storage life of the fruit but not as much as did air purification.

TABLE V—DAYS STORAGE LIFE ADDED AS A RESULT OF TREATMENT FROM STANDPOINT OF FRUIT FIRMNESS

Storage No.	Varieties in Room	Oiled Paper	25 Per Cent CO_2 5 Days	50 Per Cent CO_2 5 Days	Activated Carbon 4/1000	Activated Carbon 8/1000
			Rhode Island Greening			
1	Greening	8	10	16	80	82
			McIntosh			
2	Mixed	—	—	—	—	46
3	Mixed	—	—	—	35	—

Reduction in Scald as a Result of Treatment

To show the "per cent of control" of severe and total scald as a result of treatment the data in Table II (storage 1) was recalculated. If there was 100 per cent reduction in scald (Table VI) that would mean that a given treatment controlled all of the scald that appeared in the untreated lots.

Table VI shows that none of the treatments entirely controlled scald on Rhode Island Greening. However, the control obtained with air purification and the carbon dioxide treatments was sufficient to be of commercial importance. Shredded oiled paper gave fairly good control of severe scald but not total scald on Greenings when stored alone. In mixed variety storage it gave no control of scald. Better results with this material have been obtained in previous studies on this variety, however (4).

TABLE VI—Per Cent Reduction in Scald as a Result of Treatment

Treatment	Varieties in Room	Per Cent Reduction in Scald	
		Severe Scald	Total Scald
Rhode Island Greening			
Shredded oiled paper	Greenings	78.6	20.04
Activated carbon 4/1000	Greenings	90.8	50.83
Activated carbon 8/1000	Greenings	96.1	83.14
25 per cent CO_2 5 days	Greenings	94.4	82.53
50 per cent CO_2 5 days	Greenings	100.0	85.84
Shredded oiled paper	Mixed	0.0	0.0
Activated carbon 8/1000	Mixed	50.0	12.8
McIntosh			
Activated carbon 8/1000	Mixed	100.0	100.0
Cortland			
Activated carbon 8/1000	Mixed	87.9	60.3

Air purification entirely controlled scald on McIntosh and did a fair job in controlling scald on Cortland. Air purification did a fairly good job in controlling scald on Greenings stored alone but not in mixed variety storage. The McIntosh apples in test storages 2 and 3 did not develop any scald in even the control rooms.

Summary

Air purification with activated coconut shell carbon added from a month to 2 months to the storage life of the fruits in this test. Increasing the number of canisters from four to eight per 1000 bushels of fruit did not materially add to the effectiveness of the treatment from this standpoint.

Air purification reduced scald about as well as carbon dioxide treatments. Some injury was experienced with 50 per cent carbon dioxide for 5 days prior to storage. Scald control on Rhode Island Greenings was much more effective with air purification when they were stored alone than when mixed varieties were in the test rooms. Air purification can not be counted upon as a scald control measure in mixed

variety rooms. On the other hand it gave more satisfactory results in this test than did shredded oiled paper.

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Morphological Development of Parthenocarpic Fruits[1]

By Louis K. Mann, *University of California, Davis, Calif.*

While there have been several studies on the physiology of fruit set — enough to indicate that it is an extremely complex phenomenon (10, 11, 12, 22, 24) — less attention has been paid to its morphology. There are, I believe, two reasons why a consideration of morphological development might be of interest.

First, if there is a uniformity of response to growth substances among morphologically distinct flower or fruit parts, the reactions of diverse fruit types may be more easily interpreted.

Second, a morphological discussion may stimulate those working on fruit set problems to observe developmental phenomena more closely. This has largely been neglected in work which has been done.

In 1890 Lewis Sturtevant (30) wrote a paper entitled "Seedless Fruit" in which he listed some 60 species of plants which had produced seedless or near seedless fruits. Felix Gustafson (13) summarized this subject again in 1942, and, in addition to extending Sturtevant's observations on natural parthenocarpy, added a list of about 30 plants on which fruits could be set by synthetic growth substances, a technique he had first shown six years earlier (9). The latter list can be extended somewhat at the present time (1).

Gustafson (13) has defined parthenocarpy rather broadly, including all seedless fruit except those in which embryo abortion is known to follow fertilization. Stout (27), Condit (2, 3), and Goodspeed (8) have discussed parthenocarpy and suggested special terms for certain types. For our purposes, Gustafson's broader definition is sufficient.

Parthenocarpy in some species is "vegetative", that is, it occurs without pollination or other stimulation; in others, it may be "stimulative", requiring pollination or stimulation of some kind, such as application of growth substances.

Before discussing parthenocarpic fruits, we should consider briefly the processes taking place when fruits develop with the usual pollination, fertilization, and seed formation.

The placing of pollen on the stigma of the pistil of the receptive flower may be considered the first step in fruit development. A hypha-like tube grows from each pollen grain, penetrating the style, entering the ovarian cavity, and growing into the ovules. On entering an ovule, the tip of the pollen tube opens and discharges two sperms into the embryo sac; one of these fuses with the polar nuclei of the sac and initiates and endosperm tissue, and the other fuses with the egg nucleus to give rise to the embryo. The endosperm, from a physiological standpoint, is a nurse tissue, providing a suitable environment during the early stages of growth for the young embryo.

The fruit grows and matures mostly by enlargment and differentiation of cells, and these changes appear to be governed by growth

[1]Paper presented at a symposium on Recent Developments in Plant Growth Regulators, Pacific Meetings of American Association for Advancement of Science, June 23, 1948.

substances or hormones, the supply of which is in turn largely dependent on the series of steps initiated by pollination. The ovary or carpel walls and the ovules are nearly always a part of the fruit. Other flower parts such as the sepals and the receptacle may also enlarge to constitute parts of the mature fruit.

Returning to the development of parthenocarpic fruit, especially from a horticultural standpoint, I think three questions should be answered:

To what extent does the ovary wall develop?
Do the seed coats grow and mature normally?
What chances are there that an embryo can be formed?

Development of the Ovary or Carpel Wall

Gardner and Kraus (6) have compared fruit development in pollinated and parthenocarpic American holly fruits — one of the few detailed histological examinations that have been reported. From external appearances at maturity and time of ripening, parthenocarpic fruits set by indoleacetic acid could not be distinguished from pollinated fruits. Microscopic examination during early development likewise showed that the whole pistillate structure was similar in both pollinated and parthenocarpic fruits. The inner layer of the ovary wall of holly becomes hard at maturity, as it does in many other fruits. The development of this layer, the endocarp, was quite normal, as was also the vascular tissue of the ovary and pedicel.

Perhaps more surprising was the lack of disorganized cell growth such as has been observed after applying indoleacetic acid to bean plants (18). The authors state that "No unregulated cell division, tumerous outgrowths, nor root primordia. . . occurs in holly pistils when sprayed with aqueous solutions of this growth substance" (6).

More familiar to most workers is the parthenocarpic tomato fruit. Undoubtedly, this fruit has been set by more growth substances, which have been applied in more different ways than has the fruit of any other plant. Here again, mature parthenocarpic fruits may be almost indistinguishable from pollinated fruits, at least in sofaras the carpel walls are concerned. While no detailed histological studies have been made, the differences in color, texture, taste, and chemical makeup (17) of the carpel wall between seedless fruit set by growth substances and pollinated fruit are remarkably small. Great variations in the fruit wall occur, of course, with different growth substances, carriers, concentrations, and environments (14, 15, 23, 28, 29), but few of these variations have not also been observed with pollinated fruits.

The normal development of the inner hard layer of the holly fruit raises an interesting question about the stone fruits such as the peach, cherry, and plum. These fruits have not been set readily by growth substances, but if the generally observed response of ovary wall development to growth substances holds for stone fruits, parthenocarpic fruit would still contain a pit, this being the endocarp or inner layer of the ovary wall and not a part of the seed.

The individual drupelets of the blackberry are similar in general

structure to the stone fruits. Marth and Meader (21) have shown for a blackberry strain having some sterility that the number of drupelets set per berry can be increased by growth substance treatment. The authors observed that "seeds" developed in these drupelets, though smaller than from pollinated drupelets. One assumes here that the "seeds" are the endocarp layer, though again no morphological studies were made.

Perhaps it may be thought that it is begging the question to ask if the ovary wall always develops in parthenocarpic fruits. The ovary wall is so conspicuous a part of the fruit in most plants that, if it did not develop, we would have no fruit at all. This is true for most plants, but there are exceptions. In both the fig and the strawberry the carpel could be absent with little effect on the edibility of the fruit. These fruits are alike morphologically in that an enlarged receptacle constitutes the major part of the fruit — the receptacle of a single flower in the strawberry, of a whole inflorescence in the fig. Both of these fruits can be set by growth substances, that is, the receptacle can be stimulated to develop as it does following pollination.

In most parthenocarpic strawberries the ovaries or "seeds", as they are popularly termed, are scattered over the surface of the fleshy receptacle. To what extent their development is normal in not known. Hunter (16) reported that the achenes "were smaller than those on pollinated fruit"; Swarbrick (31) stated that "each one (fruit) had some seeds but they were often sparsely distributed"; and Gardner and Marth (7) found "apparently normal achenes which, upon subsequent examination proved to be devoid of embryos". Most interesting is the observation of Zimmerman and Hitchcock (35) who stimulated fruit set on non-pollinated flowers by vapors of methyl naphthaleneacetate. These flowers "were induced to develop receptacles which ripened in the normal way, but had few or no achenes".

If achenes are lacking, we have an example of parthenocarpic fruit without carpel development. One might suspect, in this instance, that the strawberry receptacle responds to lower concentrations of chemicals than do the achenes, but contrary to this, Gardner and Marth stated that "in the lower concentrations the receptacles made only slight initial growth, which soon ceased, although achenes usually developed". Further comparisons of these reports are difficult because of differences in varieties, growth substances, and methods of application used by these workers.

Recently Crane and Blondeau (4) have shown that the Calimyrna fig, a variety requiring pollination or caprification, can be set by growth substances. They report that such figs are seedless.

Now the "seed" of a fig is again a misnomer, at least to the botanist. The inner layer of the ovary develops into hard tissue, the endocarp, and gives the hardness to the so-called seed (2). The histology of the fruits set by growth substances has not been investigated, but it would seem that "seedless" means that the carpel wall, or at least the endocarp, has not followed its usual development. This is interesting because the endocarp apparently does develop in the naturally parthenocarpic Mission and Kadota figs. Thus, strawberry or fig receptacles,

which form the larger part of the fruit, may be stimulated to enlarge with partial, or possibly no, development of the carpels.

Seed Coat Development

While carpel or ovary wall development is normal or nearly so in most fruits set by growth substances, seed coat development is much more variable.

Gardner and Kraus (6) in their study of holly fruits found seed coat growth almost identical in pollinated and parthenocarpic fruit. The tomato, on the other hand, is seedless, almost without exception, when set by growth substances. Considering all plants in which fruits have been set by growth substances, in perhaps 80 per cent or more, the seed coats do not develop.

In some fruits like the watermelon, the seed coats almost invariably develop. Horticulturally, this is very disappointing, and here the term seedless fruit as a substitute for parthenocarpic fruit is misleading. Though viable seeds do not develop, the practical advantages of seedlessness are not attained.

Why seed coats develop in some fruits and not in others is not known. There is considerable variability among closely related plants. Thus, for *Cucurbita pepo,* Wong (34) reported that Early Prolific Straight Neck contained empty seed coats while Dark Green Zucchini had no seed coats at all. Wong (33) has reported that he stimulated the set of a "perfectly seedless" watermelon, while Howlett (15, p. 179) stated that hollow seeds "almost as large as seeds would normally be" were present in all parthenocarpic fruits he had examined.

Van Overbeek, *et al* (24) found for *Melandrium* that growth substances applied to the exterior of the ovary induced parthenocarpy but not seed coat development. Injections of growth substance solutions into the ovary cavity by a hypodermic syringe induced growth in both the ovary wall and seed coats. This work suggests that concentration of chemical, or possibly the time that it reaches the ovules, may affect seed coat development. Seed coat development is certainly a problem of practical interest deserving more attention of the hormone physiologist.

Development of the Embryo

In fruits set by growth substances no embryos have been observed. Even in the holly fruits which developed normal ovary walls and seed coats, the seeds were empty, the one distinguishing feature of the mature parthenocarpic fruit.

Perhaps it is not surprising that embryos do not develop, since in the absence of pollen, the egg is not fertilized. However, among plants many instances of embryo development in the absence of fertilization of the egg are known. These apomictic embryos develop by very diverse means, both with and without pollination; and there is no reason, *a priori,* why growth substances might not stimulate embryo development, especially where seed coats are formed.

Seeds from fruits set by growth regulators have been checked for viable embryos by several workers (7, 16, 19). Van Overbeek, *et al*

(24) have made one of the few attempts to induce development of apomictic embryos. In *Datura* they report that about one in 10,000 seeds from pollinated plants is haploid. To induce embryo formation in unpollinated flowers, a large number of chemicals known to affect growth processes were injected into ovaries treated with naphthalenacetic or indolebutyric acid. Parthenocarpic fruits were set, seed coats developed, and large masses of cells grew from the ovular tissue and filled the embryo sac cavity, but these did not differentiate into embryos. Similar development of meristematic tissue within the embryo sac has been observed by Sachet (25) in species crosses in *Datura* in the absence of growth regulating chemicals. Considering the interest of both the cytologist and geneticist in the development of apomictic embryos, the possibility of producing viable embryos should be constantly considered by those using chemicals to stimulate fruit development.

Thus, so far, initiation of embryos by growth substances in the absence of pollination has not been possible. From the horticultural standpoint, it is evident that in those crops where the seed (embryo) is used, such as dry beans or peas, no yield benefit can come from using growth substances as a substitute for pollination.

It should be kept in mind that the remarks made apply only where growth substances are used in the absence of pollination. Recently, and especially among plant breeders, growth substances are being used in conjunction with pollination. This may be done to prevent abscission, for example, of the style of cherries (19), or of the whole flower of beans (5), though it is not clear that abscission is ever a primary cause of poor fruit set. The effects of growth regulators on pollen tube growth have also been studied (19, 20, 26), especially where incompatibility results from faulty pollen tube growth. In cantaloupes, growth substances aid, to some extent, in bringing hand pollinated fruit to maturity (32). Abscission here does not seem to be a problem, as young cantaloupe fruits may remain on the vine many days after they cease to grow. We have studied the ovaries following pollination and find that fertilization, and endosperm and embryo development apparently proceed normally.

These problems are mentioned because they are morphologically quite distinct from the setting of fruit in the absence of pollination. The physiologist especially must keep these differences in mind in seeking functional interpretations of growth substance effects.

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Parthenocarpy in Caprifigs[1]

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Parthenocarpy in figs and caprifigs was discussed in a previous paper (2). In that account it was not stated that development of caprifigs inhabited by the fig wasp (*Blastophaga psenes* L.) is a good illustration of stimulative parthenocarpy. The statement was made, however, that "two seedling caprifigs which are completely parthenocarpic have recently been found among several hundred others in our seedling fig plots at Riverside, California". This vegetative parthenocarpy, with especial reference to seedling caprifigs, seems to be worthy of further discussion.

Vegetative parthenocarpy in caprifigs has long been known in Europe and in California, and one variety, the Cordelia or Croisic (3), is propagated and grown to a limited extent for its edible fruit.

Three Kinds of Parthenocarpic Caprifigs

In seedling caprifigs three general kinds or degrees of parthenocarpic development may be recognized. The first kind results in the production of figs commonly known to growers as "blanks". Eisen (6) called these figs "polleniferous"; Condit and Flanders (5) applied to them the term "uninhabited figs", since the pistillate flowers do not harbor the blastophaga. Moreover, these pistillate flowers remain entirely undeveloped. The variety Roeding No. 1 is a good example of this class of caprifig. It is no longer grown because a large proportion of its crop consists of "blanks".

In the second class of parthenocarpic caprifigs, the syconium wall or meat of the fig remains pithy and dry until maturity. The stamens usually develop properly and produce an abundance of pollen. In some figs the anthers become atrophied and appear rusty or black in the mature fruit. The development of the ovaries of the pistillate flowers into seedlike bodies or cenocarps differentiates this class from the first. These cenocarps gradually develop a sclerified ovary wall and have the appearance of seeds, but they are really empty achenes, and resemble very closely the ovaries normally inhabited by blastophagas.

In the third kind of parthenocarpic caprifigs, cenocarps develop as in class two. As the figs approach maturity, however, the spongy wall of the syconium and the parenchyma cells of the pistillate flowers gradually become pulpy and develop a certain amount of sugar. These caprifigs are in most respects similar to edible figs. It is to this class that the Cordelia belongs. The only objection to these caprifigs from the standpoint of edibility is the presence of stamens and the mass of dry pollen in the mature fruit.

In the parthenocarpic caprifigs of the second and third classes, the number of cenocarps varies greatly. Actual counts made of cenocarps in two typical figs from each of 24 different seedlings show that the

[1]Paper No. 588, University of California Citrus Experiment Station, Riverside, California.

number ranges from 36 to 1,592 per fig, the average count being 584. These figures compare favorably with the number of sterile and fertile achenes found in edible figs of named varieties [see Condit (4), pp. 40 and 44]. The number of staminate flowers in a single caprifig varies from 70 to 294 and averages 180.

Characteristics

Some standard varieties of caprifigs are invariably white inside regardless of the presence of blastophagas; others are pink inside when uninhabited by fig insects, and various shades of violet when inhabited. The same color condition is found in parthenocarpic caprifigs, some seedlings bearing syconia which are pink or violet inside. The intensity of the violet color is a characteristic of the individual seedling and is not dependent upon the number of cenocarps present.

Blastophagas enter parthenocarpic caprifigs and oviposit in the pistillate flowers. As explained in a previous article (1), both the cells of the stigmatic surface and those lining the stylar canal are injured and become discolored as the result of oviposition by the fig wasp. In the same syconium these discolored flowers can be readily distinguished from flowers with white, succulent stigmas uninjured by the wasp. However, the inhabited caprifigs can not be distinguished from the uninhabited by external appearances. Uninhabited caprifigs are of no value to the grower since there are no blastophagas present to distribute the pollen. The reason for the practical worthlessness of a parthenocarpic caprifig is therefore obvious. In a good caprifig variety the "blanks" shrivel and drop before the inhabited figs are ready to mature. A grower can then estimate the crop available for caprification.

Another noteworthy character of a good caprifig tree is an abundant profichi or June crop. In this crop, from winter buds, the caprifig tree will produce 100 to 1,000 times as many syconia as trees bearing edible figs. On the other hand, caprifigs of the mammoni or summer crop are few in comparison with the abundant second or main crop of edible figs. It is expected that eventually one or more parthenocarpic caprifigs will be found bearing a heavy crop of pulpy profichi in which the stamens are absent or so reduced in number that the figs may be marketed as fresh figs.

The possible line of evolution of the edible fig is indicated by characteristics of these parthenocarpic caprifigs. Natural selection through countless generations of chance seedlings may have evolved a type of fig without stamens or with only rudimentary ones, and pistillate flowers wtih the style three times the length of the style found in caprifigs. Trees bearing such figs would be notable for their abundant crop of edible first-crop figs or brebas. This is one of the characters of the class of figs known as White San Pedro, which includes such varieties as Dauphine, King, and Blanquette. These figs are useful for culture in cool climates in which the breba crop is the important one or possibly the only one which matures well during the season.

The quality of edible caprifigs naturally varies considerably — some are rather dry and punky, others are soft and have the consistency of

good varieties of fresh figs. The sugar content of five parthenocarpic caprifigs (four seedlings and Cordelia) is shown in Table I, in com-

TABLE I—SUGAR CONTENT OF FIGS (AS INVERT SUGAR)*

Fig Number or Variety	Moisture (Per Cent)	Total Sugars (Per Cent)		Reducing Sugars (Per Cent)		Sucrose (Per Cent Difference)	
		Moist Basis	Dry Basis	Moist Basis	Dry Basis	Moist Basis	Dry Basis
Caprifig:							
Seedling 35 2	85.27	8.51	57 77	8.42	57.16	0.09	0.61
Seedling 75-29	84.85	8.33	54.97	8.05	53.12	0.28	1.85
Seedling 75-97	85.34	9.79	66.76	9.42	64.24	0.37	2.52
Seedling 75-4	85.88	9.94	70.38	9.65	68.33	0.29	2.05
Cordelia	83 47	10 41	62.97	9.72	58.80	0.69	4.17
Mission	83 79	12 34	76.10	11.50	70.92	0.84	5 18

*Analyses by W. B. Sinclair and Paul R. Crandall.

parison with that of Mission, a standard variety of the common type. Although the average sugar content of the caprifigs is not as high as that of the Mission, it is high enough to make them palatable as well as nutritious. The combination of heavy crop and good sugar content suggests the possibility of raising parthenocarpic caprifigs for the production of by-products such as hog and cattle feed, syrup, and alcohol.

Parthenocarpic caprifigs are seldom found in the progenies of crosses involving Smyrna-type figs as the female parent. Of those which are found, none reach the third or pulpy stage mentioned above. On the other hand, a considerable percentage of parthenocarpic caprifigs occurs in progenies resulting from crosses of common figs. The significance of parthenocarpy in relation to fig breeding is therefore evident. In breeding for improved caprifigs, parthenocarpy in either parent is undesirable. In breeding for improved edible figs of the common type which are parthenocarpic in one or more crops, complete parthenocarpy and pulpiness of fruit are characters very desirable in both parents.

SUMMARY

Vegetative parthenocarpy is well exemplified in common figs and in some caprifigs. Three kinds or degrees of parthenocarpy are found in caprifigs — in the first, no cenocarps or seedlike bodies occur; in the second, cenocarps are found but the syconia are dry at maturity; in the third, numerous cenocarps occur and the mature syconia are pulpy and more or less edible, a character which suggests the possibility of growing these figs for stock feed or for by-products. As many as 1,592 cenocarps have been counted in one syconium. Parthenocarpic caprifigs may or may not be inhabited by the fig wasp (*Blastophaga psenes* L.). Many of these figs contain an abundance of pollen which can well be utilized in fig breeding if both male and female parents have desirable characters.

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The Use of Growth-Regulating Chemicals to Induce Parthenocarpic Fruit in the Calimyrna Fig

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ABSTRACT

This material will be published in full in *Plant Physiology*.

THIS paper presents the preliminary results of investigations on the chemical induction of parthenocarpic development in the Calimyrna fig. This variety, as well as all varieties belonging to the Smyrna group, requires cross-pollination in order for the syconia to set and mature.

Aqueous sprays containing indolebutyric acid at concentrations of 1500 and 2670 ppm, and an oil emulsion spray containing 2670 ppm of indolebutyric acid resulted in parthenocarpic fruit set that was equal to or better than the caprified (pollinated) controls. Neither naphthoxyacetic nor 2,4–dichlorophenoxyacetic acids at the concentrations used were effective in promoting parthenocarpy. No apparent foliage injury resulted from applications of 2,4–dichlorophenoxyacetic or naphthoxyacetic acids but indolebutyric acid caused moderate curling of the foliage accompanied by chlorosis which persisted throughout the season.

A higher percentage of figs were set when treatments were made about the middle of the caprification period than when they were made either at the beginning or toward the end of this period. By applying an aqueous spray of indolebutyric acid at the proper time, the data presented indicate that it may be possible to set parthenocarpically nearly all the synconia on the tree.

The injection of these growth regulators through the ostioles and into the cavities of figs produced no consistent parthenocarpic development. However, some figs treated in this manner reached full maturity just 12 days after treatment, as compared to approximately 80 days for caprified and 95 days for parthenocarpic figs induced through spraying.

Parthenocarpic figs were not markedly different from caprified fruits as regards color, size, shape, flavor, and sugar content, but they were completely seedless with no sclerification of the ovary walls.

Fruit Growth of Four Fig Varieties as Measured by Diameter and Fresh Weight

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STUDIES of drupaceous fruits such as the apricot (4), cherry (7), peach (5), and plum (6) have shown that growth of these fruits is segregated into three distinct periods. The first period, following fertilization, is characterized by a rapid rate of growth. The second, during which the kernel is formed and the stone hardens, is evidenced by a much depressed growth rate. The third period, in turn, consists of an accelerated growth rate of the flesh to maturity, being referred to as the period of "final swell". When the growth increments of these periods are plotted, a double sigmoid curve is obtained. Data are presented here to show the existence of a similar periodicity in growth of the fig fruit.

The four commercial fig varieties produced in California, Mission, Adriatic, Kadota, and Calimyrna are distinctly different in regard to such factors as true growth habit, fruit characteristics, pollination requirements, adaptability to usage, and, to some extent, cultural methods (2). For these reasons, the type of fruit growth of each variety has been determined.

Most varieties of figs bear two crops of fruit under the environmental conditions best suited to their culture. The first crop is borne on wood of the previous season's growth from buds differentiated in the distal leaf axils during the latter part of the growing season. These buds become active the following spring and mature into fruit during the month of June. This crop of fruit is termed the breba crop. The second crop of figs is produced on shoots of the current season, usually one fig in the axil of each leaf with the exception of two or three leaves at the distal end of the shoot whose axial buds give rise to the first crop of fruit the following year. The second crop of figs begins to mature at the proximal end of the shoot the latter part of July and there is a succession in maturation as long as weather conditions are favorable.

The only one of these four varieties that produces a breba crop of much commercial importance is the Mission. With the exception of this variety, of which both crops will be discussed, it is, therefore, the second crop that is referred to here with regard to fruit growth characteristics of varieties other than the Mission.

In contrast to the Mission, Adriatic, and Calimyrna varieties, which are used primarily for drying, the Kadota fig is grown principally for canning. Trees of the former varieties are allowed to grow more or less naturally and pruning of bearing trees merely consists of an occasional thinning-out and heading-back of the top in order to stimulate the growth of new wood on the main framework branches. Depending upon vigor of the tree, 6 to 12 inches of shoot growth is made currently on each branch and from three to seven second crop figs are produced in the axils of the leaves on this new growth. Upon maturing, fruits of these varieties drop to the ground, after which they are

picked up at intervals. For this reason, there is little attempt made to control height and size of tree.

In order to facilitate economical harvesting of the crop, Kadota trees are trained to obtain a low, nearly flat-topped tree so that all fruit may be harvested by pickers standing on the ground. After the framework is formed, pruning of Kadota trees consists of thinning-out and heading-back the 1-year wood remaining to short stubs. As a result of this practice, all wood that potentially bears a breba crop of figs is removed and, consequently, only a second crop is produced. The second crop is borne in the axils of leaves on shoots 2 to 5 feet in length that arise from the stubs left in removing the previous season's growth. These long shoots may have 10 to 20 nodes and produce 10 to 25 figs, occasionally two figs being found in a single leaf axil.

The Mission, Adriatic, and Kadota varieties are completely parthenocarpic in that the flowers do not require the stimulus of pollination and fertilization to make the fruit set (1). The flowers of these varieties are usually unpollinated and the fruits contain fairly numerous fruitlets (achenes) with no embryos. The Calimyrna variety, on the other hand, is almost completely non-parthenocarpic and the flowers require the stimulus of pollination and fertilization in order for the fruit to set. Calimyrna figs, therefore, characteristically contain numerous fertile fruitlets, that is, with viable embryos.

Materials and Methods

Four trees of each variety were selected and fruits on 25 limbs per tree distributed at random were tagged. In order to determine the relationship of fruit growth to position on the shoot, measurements were made of fruits at every other node, beginning with the first fruit at the base of the current season's growth. In other words, 100 fruits of the same age or at every other node position were measured on each of the four varieties. On the more vigorous Kadota variety, fruits at eight different node positions were measured, but on the less vigorous Mission, Calimyrna, and Adriatic varieties, fruit measurements were made at node positions 1, 3, and 5. The Mission variety, where measurements were made on the breba crop as well as the second crop, generally produces a breba fig at each of the two distal-most nodes on the previous season's growth. In some cases only one fig per shoot is produced while in others three or more are borne at as many nodes. For the purpose of measuring fruit growth, however, 25 branches bearing two figs per branch on each of four trees were selected.

Cross-diameter measurements with a vernier caliper were made at weekly intervals from the time the fruits were about 5.0 mm in diameter until maturity. Measuring was started on the breba crop Mission figs the middle of March and continued until the end of September when final measurements were collected on the last of the Kadota figs to mature. A total of approximately 25,000 individual measurements were made on fruits of the four varieties at the different node positions on the shoots. In general, each average measurement is based on 100 fruits.

The loss of fruits originally tagged was negligible with the exception of the Calimyrna variety which, as pointed out above, requires cross-pollination. Whenever possible, a tagged fruit that dropped early in the season was replaced with another fruit of approximately the same size.

On each date of measurement, 50 fruits were picked from the first or basal nodes of the current season's shoots on neighboring trees in order to trace growth throughout the season as measured by fresh weight of the fruit.

Results and Discussion

The data in Table I, comparing the periods of growth and growth rates, as well as the curves of growth in Fig. 1, show there was a remarkable similarity in fruit growth habit of the four varieties of figs. This is somewhat contrary to what was expected in view of the marked varietal differences which were briefly discussed above.

Considering fruit growth characteristics of the four varieties collectively, it is noted in Table I that growth took place at a com-

TABLE I—Comparative Periods of Growth* and Growth Rates of Four Varieties of Figs as Related to Fruit Position on the Shoot

Variety, Crop and Node Position	Period I			Period II			Period III		
	Extent (Days)†	Growth (Mm)	Rate Per Day (Mm)	Extent (Days)	Growth (Mm)	Rate Per Day (Mm)	Extent (Days)	Growth (Mm)	Rate Per Day (Mm)
Mission									
Breba crop 1	55	26.3	0.48	39	1.5	0.04	11	7.8	0.71
2	51	26.3	0.52	39	1.3	0.03	14	7.5	0.54
Average	53	26.3	0.50	39	1.4	0.04	13	7.7	0.63
Second crop 1	39	20.1	0.52	40	3.2	0.08	20	10.8	0.54
3	40	19.2	0.48	40	3.4	0.09	21	9.1	0.43
5	40	17.1	0.43	41	4.6	0.11	22	9.4	0.43
Average.....	40	18.8	0.48	40	3.7	0.09	21	9.8	0.46
Kadota									
Second crop 1	36	20.2	0.56	50	3.8	0.08	14	10.3	0.74
3	37	21.4	0.58	42	2.4	0.06	22	11.0	0.50
5	36	21.1	0.59	43	3.1	0.07	21	9.5	0.45
7	30	21.0	0.70	43	3.1	0.07	21	10.6	0.50
9	32	19.1	0.60	43	2.4	0.06	21	9.4	0.45
11	40	19.6	0.49	36	1.8	0.05	20	9.2	0.46
13	39	20.3	0.52	42	3.4	0.08	21	9.2	0.44
15	38	21.8	0.57	41	4.0	0.10	22	8.7	0.40
Average.....	36	20.6	0.58	43	3.0	0.07	20	9.7	0.49
Adriatic									
Second crop 1	39	23.9	0.61	41	6.1	0.15	35	7.9	0.23
3	37	21.7	0.59	41	6.4	0.16	42	7.7	0.18
5	41	22.9	0.56	42	4.5	0.11	35	9.3	0.27
Average.....	39	22.8	0.59	41	5.7	0.14	37	8.3	0.22
Calimyrna									
Second crop 1	48	26.8	0.56	36	2.9	0.08	22	11.8	0.54
3	46	27.5	0.60	34	2.6	0.08	29	11.4	0.39
5	41	28.2	0.69	36	1.4	0.04	21	14.2	0.68
Average.....	45	27.5	0.62	35	2.3	0.07	24	12.5	0.34

*As measured by fruit diameter.
†Beginning at the time the fruits were about 5.0 mm in diameter.

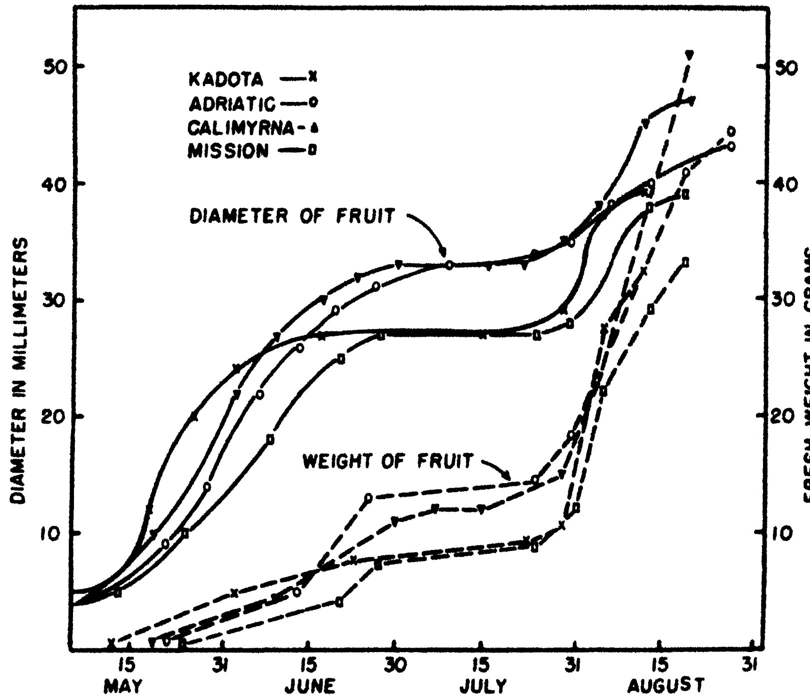

FIG. 1. Growth of four varieties of second-crop figs as measured by diameter and fresh weight of the basal fruit on current season's growth.

paratively rapid average rate of from .48 mm to .62 mm per day during the first 36 to 53 days, depending upon variety. For the next 35 to 43 days, growth was practically at a standstill. During this period an average increase in diameter of 1.4 to 5.7 mm took place at a daily rate of from .04 to .14 mm. In this connection, it will be noted that the Adriatic variety was somewhat different from the others. Although the duration in days was similar, the rate of growth and average increase in diameter during the second period were considerably greater in this variety than for the others. Following the period of depressed growth, with a marked abruptness the fruits of these varieties again grew rapidly until their ultimate diameters were reached. This final growth period extended from a 13-day interval in the case of breba Mission figs to a period of 37 days in the Adriatic variety.

The increase in fresh weight of fruits of the four varieties of figs is presented graphically in Fig. 1. The periodicity that takes place in growth as measured by fruit diameter was present, likewise, when the weight of the fruit was considered. The rapid rate of increase in weight of the fig fruit during the last period of growth is quite similar to what has been reported for stone fruits (4, 5) where two-thirds of the weight of the mature fruit was produced during the last period of growth.

It is interesting that the fig fruit, botanically a fleshy receptacle, follows a growth pattern like that of drupaceous fruits where no receptacular tissue is present rather than like the pome fruits. Diameter measurements of apples in Oregon (12) and volume measurements of apples and pears in California (3) do not show any cyclic growth.

In an attempt to explain the cause for the occurrence of the period of retarded rate of size increase, various hypotheses have been advanced but their validity has not been satisfactorily proven. Lott (11) raised the question as to whether wall thickening and other changes in the flesh cells were responsible for the retarded rate of size increase of the flesh and pointed out the need for information on the histological behavior, during this period, of different varieties during different seasons of ripening.

Based upon the fact that, when dry-weight increase was used as the measure of growth of several peach varieties, no clearly defined period of depressed growth rate was evident, Lott (9, 10, 11) suggested that dominance of the stone controlled the development of the flesh. He found that the amount of dry matter, hemicellulose, and lignin in the stone increased rapidly during the second period while the rate of accumulation of these materials in the flesh was low. Should this flesh-stone relationship be of importance in drupaceous fruits, evidence to the contrary in the case of the fig is presented in Fig. 2, which shows growth curves of normally pollinated and growth regulator-

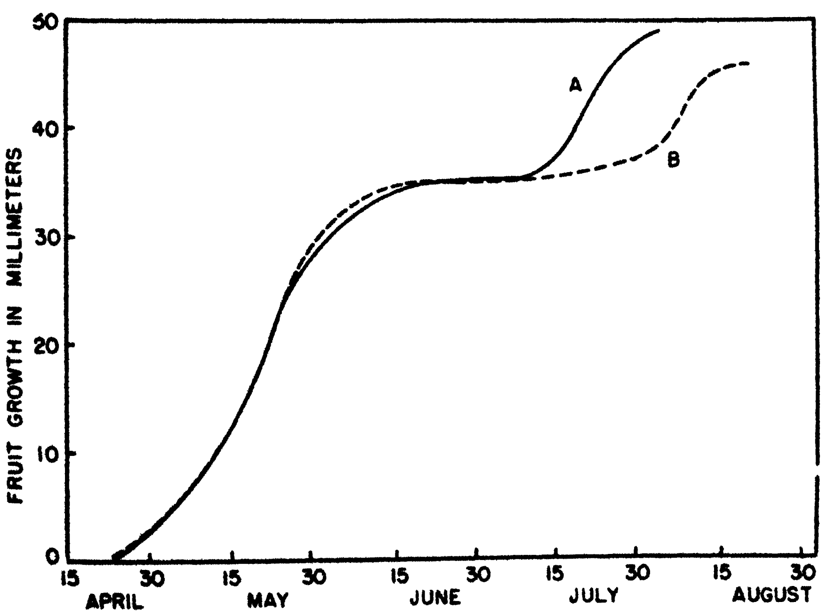

Fig. 2. Typical curves of growth of pollinated (A) and parthenocarpic (B) Calimyrna fig fruits.

induced parthenocarpic Calimyrna fig fruits.[1] Attention is called to the fact that the rates of growth during most of period I were identical for those fruits that were destined to develop parthenocarpically and those that were to produce seeds as a result of pollination. Shortly after indolebutyric acid (1500 ppm) was applied in the form of an aqueous spray on May 24, fruits so treated grew at a somewhat more rapid rate, but later ceased enlargement in period II at the same average diameter as fruits that were pollinated. A difference of about 20 days in the length of time the two types of fruit remained in period II was responsible for the fact that parthenocarpic fruits did not mature until about 2 weeks after maturation of fruits that were pollinated. It should be pointed out here that there was a complete absence of seeds in the parthenocarpic fruits, even to the extent that sclerification of the ovary walls was not in evidence.

Since periodicity in growth has been shown to be independent of cultural practice, seasonal fluctuations in temperature and moisture, competitive growth processes in other parts of the tree, length of the growing season, size of crop (4, 5, 8), or, as shown here, of dominance of reproductive over vegetative tissues, it is logical to assume that cyclic growth may be due to some physiological factor such as variation in supply or activity of a hormone or an enzyme within the plant or fruit itself.

It is evident in Fig. 3 that fruits of the two crops of Mission figs, borne on the same branch, overlapped in their respective growth periods. At the time breba figs were in period II, the period of depressed growth, the second crop figs were going through period I, a period of rapid growth. Likewise, in Fig. 4, it may be seen that Kadota

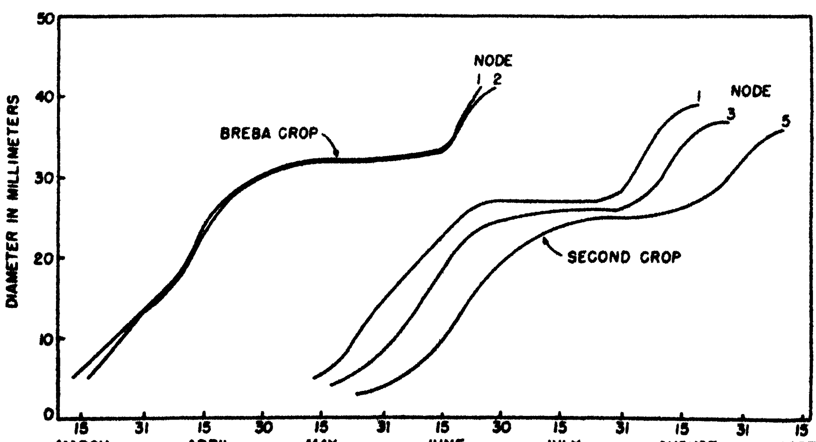

FIG. 3. Relationship of growth, as measured by fruit diameter, of the Mission fig breba crop to the second crop and to the position on the shoot.

[1]Complete details of this work are published elsewhere. Grateful acknowledgement is made to Rene Blondeau, Shell Agricultural Laboratory, Modesto, California, for his cooperative efforts in this connection.

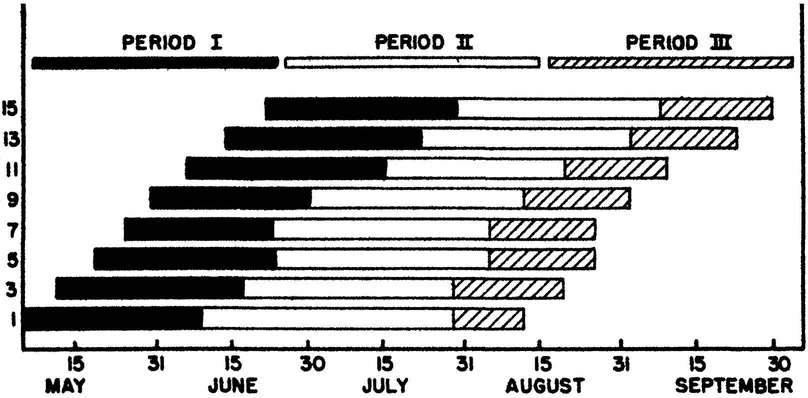

FIG. 4. Relationship of position on the shoot to the periods of growth of Kadota fig fruits.

figs at nodes 13, and 15, for example, were growing at a rapid rate in period I while fruits at the first node position were in a depressed state of growth, or period II. Similarly, fruits at node positions 1, 3, 5, 7, and 9 were in period III at the same time fruits at nodes 13 and 15 were going through period II in development. Apparently, the hormone or enzyme associated with fruit growth, should this be the case, is produced in the leaf subtending the fruit or, more likely, within the fruit itself. Data presented in Fig. 2 are indicative of the fact that the growth regulating substance is produced partially, if not wholly, within the fruit itself since the duration of period II was lengthened by parthenocarpy.

Regarding fruit growth in relation to position on the shoot, it is of interest to note in Fig. 3 the comparative differences in growth of breba and second crop Mission figs. From the time the fruits were 5.0 mm in diameter to the inception of period II, about 13 days more elapsed in the case of breba figs than for the second crop fruits. As a result, breba figs passed through period II at an average diameter of 32 mm, while the second crop figs were from 5 to 8 mm smaller during this period. Perhaps, as a result of competition among fruits, breba figs had a duration of about 13 days in period III as compared with 21 days for second crop figs.

Fig. 4 presents graphically the comparative periods of growth of Kadota figs at every other node on the shoot. It will be noted that all fruits passed through the tree periods of growth and the duration of each respective period was very much the same irrespective of fruit position on the shoot. In general, there was about a week's difference in degree of development between every other succssive fig on the shoot.

SUMMARY

Diameter measurements at weekly intervals showed that fruits of the Mission, Adriatic, Kadota, and Calimyrna varieties of figs, although morphologically quite different from drupaceous fruits, ex-

hibited periodicity in growth similar to what has been reported for the peach, apricot, and other stone fruits.

Data are presented which show that growth of both normally pollinated and growth regulator-induced parthenocarpic Calimyrna fig fruits was similar and cyclic in nature. This evidence suggests that some factor or factors other than dominance of the reproducive tissues controls growth of the flesh of the fruit.

It is suggested that cyclic growth may be due to some physiological factor such as variation in supply or activity of a hormone or an enzyme. Evidence is presented which shows that, should this be the case, the material is not systematic but is localized within the fruit.

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Specific Gravity of Citrus Fruits[1]

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Specific gravity is a relatively fundamental property of solids, and its importance in various theoretical and practical calculations is generally recognized. Specific-gravity determinations on citrus fruits can, however, in addition, be used to separate fruit of good edible quality from poor. Separation of frozen fruit from unfrozen fruit in about 75 per cent of California commercial packing houses is effected on this basis, although such separation in the washers is gradually being replaced by X-ray and fluoroscopic methods. The effect of factors other than freezing, on the quality of citrus fruit, also may be judged on the basis of specific gravity. For instance, "granulated" fruit probably could be detected and separated from healthy fruit without the use of X-rays or by cutting samples.

In resistance to insecticidal and fungicidal sprays and dusts, and in keeping and shipping qualities, coastal-grown fruit ranks lower than fruit from the interior valleys. The reasons for these differences have not been apparent in cursory experimental work aimed to explain them, though fruit from the coastal regions is said to be more tender than that from the interior, and this quality may be reflected in their water content and thus in their specific gravity.

Following the "freeze" in California in 1913, a number of papers were published (1, 8, 10), giving values of specific gravity for frozen and unfrozen stored and freshly picked oranges and lemons. Since the publication of these papers, no further work has appeared. After the lapse of more than 27 years, there is need for additional data on the specific gravity of citrus fruits, relative to the climatic types of citrus-growing areas, and the various commercial varieties.

Materials and Methods

Citrus fruits are grown under a wide variety of climatic and soil conditions in California. These citrus-growing areas may be classified as coastal, intermediate, interior valley, and desert sections (9), and are characterized by a climatic gradient that is cool to hot, and moist to very dry.

Ripe fruits from the various kinds of citrus trees were picked at random and each sample consisted of a wide variety of sizes. Short stems were left attached until the fruits were ready for measurement. From such fruits, 30 to 150 that were without scratches, punctures, insect markings, or other imperfections of the peel were selected for use in a given specific-gravity determination. The equatorial and polar axis of each fruit was measured and its specific gravity determined. Great care was taken not to bruise the fruit. These and other precautions were taken to avoid any sizeable water losses from the fruit before measuring. Usually, measurements were begun immediately after picking, or within 2 hours. Fruits that could not be measured immedi-

[1]Paper No. 585, University of California Citrus Experiment Station, Riverside, California.

ately were placed in paper bags in an ice refrigerator. All measurements, however, were completed less than 12 hours after the fruits were removed from the trees.

Four methods tested in determining specific-gravity values are described below. The comparative accuracy of these methods is shown in Table I.

TABLE I—STANDARD ERRORS OF SPECIFIC-GRAVITY DETERMINATIONS ON ONE FRUIT (REPLICATED FIVE TIMES FOR EACH OF FOUR METHODS)

Method*	Specific Gravity	Standard Error
Tables	0.969	±0.0315
Volumetric (N)	0.903	±0.0254
Volumetric (P)	0.897	±0.0027
Gravimetric	0.905	±0.0016

*(N), nonprecision; (P), precision.

1. *Tables:*—The major and minor axes of fruits were measured to 0.01 cm with a micrometer, and volumes (V) for these measurements were obtained by means of tables of spheroidal values (6, 7). Mass (M) was determined with a balance weighing to 0.1 gram, and specific gravity (D) was determined from the formula $D = \frac{M}{V}$.

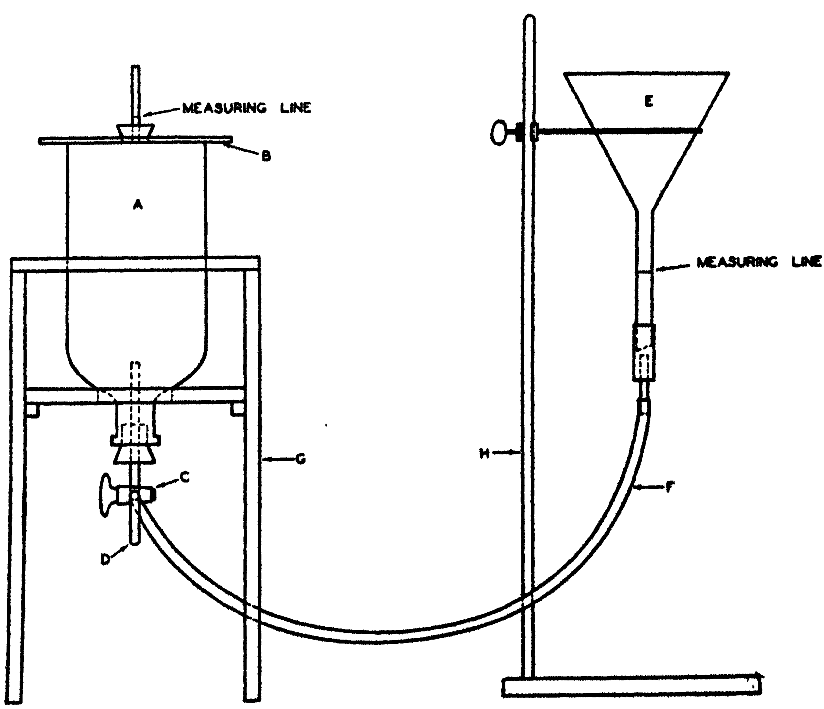

FIG. 1. Apparatus for the precise determination of fruit volume. A, 2.5-liter acid bottle; B, Plate-glass plate; C, Three-way "T" stopcock; D, Outlet; E, 750-cc glass funnel; F, Rubber tubing; G, Wooden stand; and H. Iron stand.

2. *Precision (P) Volumetric:*—A 2.5-liter acid bottle was cut off at the base and ground to fit a plate-glass plate (Fig. 1, B) which had a hole drilled in the center to permit the fitting of a stopper carrying a glass tube of small bore, bearing a measuring line. The bottle was placed in a wooden stand (G), with the neck down and fitted with a stopper and a T-shaped, three-way stopcock (C), one side of which was connected by a rubber hose (F) to a large (750-cc) glass funnel (E) bearing a measuring line on the stem.

In making a volume measurement, stopcock (C) was opened so that communication was established between bottle (A) and funnel (E). The bottle (A) was filled with water, the funnel (E) being partly filled, and the ground glass plate (B) placed on the top of the bottle. The funnel was then raised to drive out the air in the bottle and any air-bubbles collecting under the glass plate (B) and force the water up to the measuring line on the glass tube. The opening of stopcock (C) was then changed so that the bottle was shut off and connection made for drawing water from the funnel to the outside through tube D. The water in the funnel was thus adjusted to the measuring line on its stem. The stopcock (C) was then turned so that tube D was closed and communication re-established between funnel (E) and bottle (A). The funnel was then lowered thus making room for the fruit in the bottle without loss of water. The fruit was carefully placed in the bottle (A), the glass plate (B) put in place and the funnel raised so that the water came up to the measuring line on the glass tube in glass plate B. By tapping plate B with a pencil all bubbles that collected at its under surface could be removed. The three-way stopcock (C) was then turned so that water was withdrawn from funnel E to the outside through tube D, until the water in the funnel E came down to the measuring line on its stem, then stopcock C was closed. The water displaced by the fruit which had been allowed to run into a tared beaker was then weighed.

3. *Nonprecision (N) Volumetric:*—The fruits were immersed individually in a gallon can filled with distilled water to the point where an overflow spout was attached, and the water which overflowed when the fruit was immersed, by means of a plunger carrying four pins, was measured in a 100-cc graduate (7).

4. *Gravimetric:*—Specific gravity of fruits in these tests was obtained primarily by the gravimetric method, as this was the most precise of the methods used (Table I). The mass (M) of the fruit, in grams, was determined on a specific-gravity balance to 0.01 gram. Mass (W_a) of the fruit in air was determined with a weight, which was hung underneath the holder carrying the fruit, submerged in water. The mass (W_s) was determined with both fruit and attached weight completely submerged in distilled water. Specific gravity (D) was calculated from the formula $D = \frac{M}{W_a - W_s}$.

Results

Mature Washington Navel orange fruits grown in the interior valley section (Table II) had a lower average specific gravity (0.931)

TABLE II—AVERAGE SPECIFIC GRAVITY OF CITRUS FRUIT FROM VARIOUS SECTIONS OF CALIFORNIA

Kind of Fruit	Section	Average Specific Gravity	Standard Error
Washington Navel orange	Interior valley	0.931	±0.0283
	Intermediate	0.969	±0.0215
Valencia orange	Interior valley	0.922	±0.0181
	Coastal	0.935	±0.0191
Eureka lemon	Interior valley	0.911	±0.0233
	Intermediate	0.934	±0.0182
	Coastal	0.953	±0.0212
Lisbon lemon	Coastal	0.921	±0.0204
Marsh grapefruit	Interior valley	0.824	±0.0304
	Desert	0.789	±0.0584

than those grown in the intermediate section (0.969). Mature Valencia orange fruits grown in the interior valley section had a lower average specific gravity (0.922) than those grown in the coastal section (0.935), but the sectional differences in Valencia oranges were by no means so large as those in Washington Navel oranges or in the other fruits measured. However, as indicated by the standard-errors, these differences are not significant.

The average specific gravity of Eureka lemons grown in the interior valley was 0.911; that of the fruit grown in the coastal districts was higher (0.953), while that of the fruit grown in the intermediate districts was intermediate between the two (0.934), but as indicated by the standard errors the differences are not significant. The average specific gravity of Lisbon lemons from the coastal section (0.921) was lower than that of Eureka lemons from the coastal section but likewise is not significant.

Specific-gravity measurements of Marsh grapefruit were made of the interior-valley fruit in the late spring and summer, and of the desert fruit in the winter and early spring, so that fruits of about the same degree of maturity from the two sections could be compared. The average specific gravity of ripe grapefruit grown in the interior valley (0.824) was higher than that of grapefruit grown in the desert section (0.789). However, the difference is not significant.

DISCUSSION

For healthy fruit of Navel orange, Young (10) reported an average specific gravity of 0.873. This is lower than any averages of specific gravity recorded by us for healthy Washington Navel orange fruits. However, a sample of granulated Valencia oranges we obtained from the coastal district had an average specific gravity of 0.851. Young (10) also found an average specific gravity of 0.876 for sound (healthy) lemons, which is lower than the average value for any sample of lemons picked in any district during our investigations. Bailey and Wilson (1), on the other hand, found that sound, unfrozen lemons grown in the intermediate section, had an average specific gravity of 0.933; this is confirmed by our value of 0.934 for the intermediate section. We have found that the specific gravity of good-

quality normal fruits of equal size does not appear to vary greatly from year to year. For example, in two successive years Valencia oranges had specific gravities of 0.897 ± 0.0238 and 0.904 ± 0.0276, the variations being within the standard error.

Valencia oranges are subject to a disorder commonly called "granulation", in which the juice gelates and fruit quality is greatly reduced (3). Fruits of two samples from widely different areas of the coastal district where the incidence of this disorder is greatest were found to be granulated when cut, and to be characterized by low average specific gravities (0.851 and 0.897).

Since colloids of living cells, as well as artificial colloids, have a decreasing water retention with increasing age (4, 5), a correlation between water content and keeping quality of citrus fruits would therefore be expected. Computations on the data of Bartholomew and Sinclair (2) show that the peel of Washington Navel oranges from the interior valley section contained an average of 75.19 per cent moisture, whereas that of fruits from the intermediate section contained an average of 78.50 per cent. In the present studies the specific gravity of Washington Navel oranges was found to be 0.931 for the interior valley section, and 0.969 for the intermediate section. This suggests that there may be a positive correlation between water content of the peel and specific gravity of the fruit. The higher water content of the peel of fruit grown in coastal regions might explain the poorer keeping and shipping qualities of fruits grown in cool, humid regions as compared with those grown in warmer, drier regions. The succulence and "tenderness" of coastal grown fruit resulting from a higher water content of the peel could also account for their lower resistance to injury from insecticides and fungicides, but although the trend is clear as shown in the specific gravity data in Table II, the fact that the differences are not statistically significant make such conclusions unwarranted.

The mean fruit size for any one crop year for a given variety of citrus fruit varies greatly (11). The effect of fruit size on a weight basis on specific gravity is shown in Table III. There is a negative correlation between specific gravity and fruit size ranging from $r = -0.3666$ to $r = -0.9409$ as indicated by the correlation coefficient for the various commercial varieties of citrus. These have been translated into regression equations (Table III) which indicate the decrease in specific gravity with increase in size of fruit. This negative

TABLE III—Regression Equations and Correlation Coefficients for Specific Gravity and Fruit Size (on Weight Basis) of Citrus Fruit

Kind of Fruit	Coefficient of Correlation (r)	Standard Error of r	Regression of Specific Gravity (D) on Weight (M)
Washington Navel oranges	−0.3666*	±0.1320	$D = 0.96527 - 0.00025254M$
Valencia oranges	−0.4264**	±0.1364	$D = 0.98815 - 0.00048839M$
Eureka lemons	−0.3965*	±0.1565	$D = 0.97920 - 0.00033749M$
Lisbon lemons	−0.9409**	±0.0213	$D = 0.96295 - 0.00045510M$
Marsh grapefruit	−0.6453**	±0.1103	$D = 0.90882 - 0.00044459M$

*Significant at 5 per cent level.
**Highly significant at 1 per cent level.

correlation between fruit size and specific gravity may be the variable responsible for the non-significant differences in specific gravity of fruit grown in different localities. If so, fruit of the same size should be used to determine locality differences in specific gravity.

SUMMARY

The specific gravities of fruit of citrus species grown in similar districts in southern California in decreasing order were: Washington Navel orange, Eureka lemon, and Marsh grapefruit but the differences though consistent were not significant.

The specific gravity of fruit of the same species grown in different localities were consistently lower in the drier regions but the differences were not significant.

There was a negative and significant correlation between size of fruit and specific gravity.

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The Ascorbic Acid Content of Nine Strawberry Varieties in Mississippi[1]

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ASCORBIC acid, vitamin C, is an antiscorbutic, water-soluble vitamin which is stored in the human body only in very limited quantities; hence, a generous daily intake is necessary. Recommended daily allowances for optimal dietary intake have been made by the Committee on Food and Nutrition of the National Research Council (9).

Strawberries are a good source of ascorbic acid and numerous workers have manifested interest in this source of ascorbic acid (1, 2, 3, 4, 5, 7, 8, 10, 11). Several factors have been reported to influence the ascorbic acid content of strawberries: varieties, (1, 2, 3, 4, 8, 10, 11) light intensity, (1, 2, 3) degree of ripeness, (1, 2, 7, 10) portion of berry sampled, (1, 7) seasonal trend, (2, 4, 7) size of berry, (10) and environment in which berries are grown (1, 2).

The large number of factors which influence the ascorbic acid content of strawberries would indicate a need for careful sampling and chemical analyses, and a statistical approach to the study of varietal differences. The objectives of this study were: (a) to determine the ascorbic acid content of several strawberry varieties grown in Mississippi to ascertain their relative value as sources of ascorbic acid for the human diet; and (b) to determine those varieties which would be suitable as parents in breeding for new varieties rich in ascorbic acid. Because of the reports of variations due to seasonal trends, there was a need for analyses on successive harvesting dates.

MATERIALS AND METHODS

The strawberry varieties Blakemore, Fairmore, Klonmore, Klondike, Massey, Missionary, Suwannee, Tennessee Beauty, and Tennessee Shipper were grown on the horticultural farm at Mississippi State College in April, 1947. The berries were harvested between 8 and 10 a.m., and 1 pint of uniformily ripe and sized berries was selected from each plot for a laboratory sample. The berries were placed in the shade immediately and within an hour they were refrigerated until the chemical analyses were started. At no time was there an elapse of more than 6 hours from the time of picking to the completion of the analyses.

The berries were quartered and ascorbic acid and moisture determinations were made on composites of opposite quarters. Ascorbic acid was determined by the Morell method (6) using a 20-gram sample of strawberries and 200 ml of metaphosphoric acid as the extracting solution. Moisture samples were dried to constant weight in a forced draft oven at 80 degrees C.

[1]Contribution from the Mississippi Agricultural Experiment Station, State College, Mississippi Published with the approval of the Director, as paper number 165, new series.

Experiments

The strawberry varietal trial from which these samples for analyses were obtained was a 3 x 3 balanced, duplicated lattice as described by Wellhausen (12), with a total of nine varieties and eight replicates. The matted rows were 20.7 feet long and approximately 24 inches wide and the middles were 18 inches wide. Samples from each plot were analyzed at weekly intervals for 4 weeks making a total of 32 analyses of each variety for the season. The results were compiled statistically in a split-plot design.

Results

Pronounced differences were observed in the ascorbic acid content of the nine varieties harvested at weekly intervals expressed either on a fresh weight basis (Table I), or on a moisture free basis (Table II).

TABLE I—Ascorbic Acid Content of the Fruits of Nine Strawberry Varieties on a Fresh Weight Basis in Milligrams Per 100 Grams of Berries

	Dates of Analyses				Averages
	May 7	May 14	May 21	May 28	
Missionary	43.53	42.50	40.15	47.37	43.39
Blakemore	47.54	48.55	44.95	49.67	47.68
Massey	54.54	50.38	42.46	43.71	47.77
Tennessee Beauty	60.06	54.35	49.26	49.05	53.18
Klondike	48.09	52.97	51.42	60.27	53.19
Klonmore	46.95	51.14	57.89	60.73	54.18
Tennessee Shipper	64.86	55.03	50.30	55.24	56.36
Suwannee	56.12	63.56	54.02	58.44	58.06
Fairmore	69.36	66.86	65.75	64.88	66.71
Averages	54.57	53.927	50.689	54.372	53.39
L.S.D. at 5 per cent	4.74	4.48	4.57	5 17	2.80
L.S.D. at 1 per cent	6.35	5.99	6.11	6.92	3.75

TABLE II—Ascorbic Acid Content of the Fruits of Nine Strawberry Varieties on a Moisture Free Basis in Milligrams Per 100 Grams

	Dates of Analyses				Averages
	May 7	May 14	May 21	May 28	
Missionary	531.63	421.06	430.21	408 88	447.95
Massey	588.15	500.72	442.90	382.85	478.66
Blakemore	602.19	492.23	481.02	426.16	500.40
Suwannee	581.52	565.46	513.63	452.82	528.36
Klonmore	598.10	492.07	543.85	482.24	529.07
Klondike	609.29	536.37	533.24	527.70	551.65
Fairmore	637.72	581.90	555.07	526.01	575.18
Tennessee Beauty	726.70	615.72	532.78	445.15	580.09
Tennessee Shipper	746.39	625.16	609.88	521.11	625.64
Averages	624.03	536.74	515.84	463.66	535.22
L.S.D. at 5 per cent	59.98	54.18	30.62	45.55	23.61
L.S.D. at 1 per cent	80.25	72.49	40.95	60.95	31.58

The seasonal average ascorbic acid content for each variety ranging from Missionary, the lowest, to Fairmore, the highest, is shown in Fig. 1. Computed on a moisture free basis, the ascorbic acid content decreased progressively for the season (Fig. 2). Pronounced differ-

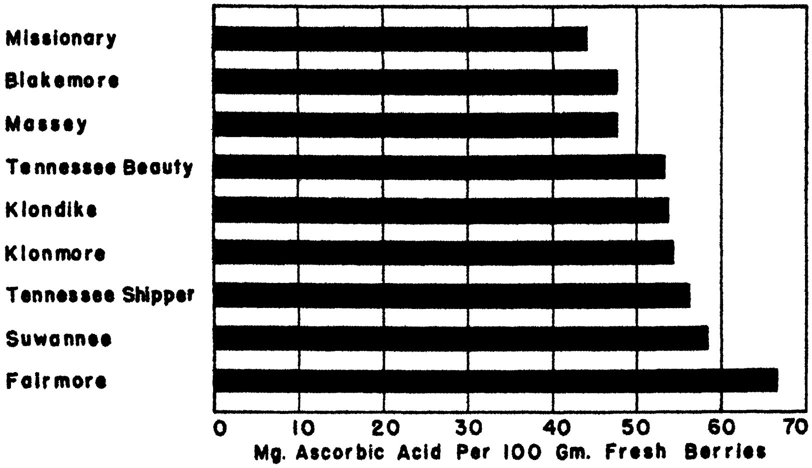

FIG. 1. The seasonal average ascorbic acid content of nine strawberry varieties at State College, Mississippi, during 1947.

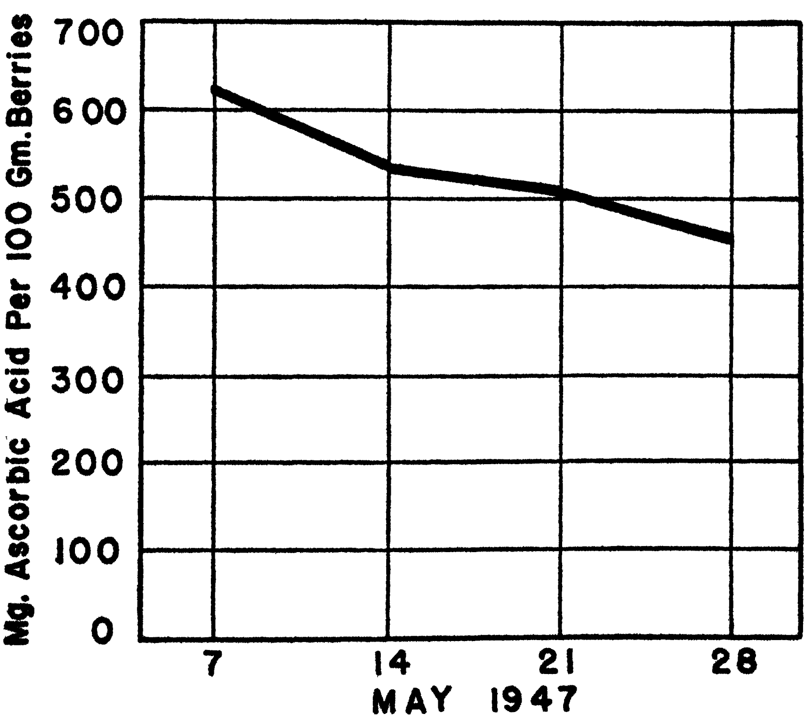

FIG. 2. The seasonal trend of mean ascorbic acid content on a moisture free basis for nine varieties.

ences in moisture content were observed between varieties (Table III).

The statistical compilation shown in Table IV indicates the size and relative importance of the variation in ascorbic acid content for varieties, replicates, blocks, and duplicates.

TABLE III—AVERAGE PER CENT MOISTURE IN THE FRUITS OF NINE STRAWBERRY VARIETIES

	Dates of Analyses				Averages
	May 7	May 14	May 21	May 28	
Fairmore	88.81	88.50	88.13	87.67	88.28
Suwannee	90.31	87.62	89.44	87.01	88.60
Klonmore	92.08	89 56	89.38	87.43	89.61
Massey	90.70	89.88	90.31	88 24	89.78
Missionary	91.80	89.94	90 75	88.56	90 26
Klondike	92 11	90.00	90.44	88 60	90.29
Blakemore	92 16	90.12	90.69	88.34	90.33
Tennessee Beauty	91 67	91.12	90.69	88 95	90.61
Tennessee Shipper	91 35	91.06	91 69	89 20	90.83
Averages	91.22	89.88	90 17	88.22	89.84
L.S.D at 5 per cent	0.91	0.91	0 57	1.05	0 48
L.S.D. at 1 per cent	1.22	1.22	0 76	1 41	0 49

TABLE IV—ANALYSES OF VARIANCE FOR THE STRAWBERRY VARIETAL TRIAL TEST IN A 3 x 3 BALANCED LATTICE DESIGN WITH FOUR REPLICATIONS DUPLICATED

Source of Variation	D F.	Mean Squares		
		Ascorbic Acid (Mg/100 Gm. Original Basis)	Ascorbic Acid (Mg/100 Gm. Dry Basis)	Moisture in Gm/100 Gm
Whole plot	71			
Reps	7	105 98†	10,804.26†	5.79†
Varieties	8	1,513.98†	97,566.23†	22.54†
Blocks				
Comp. a	8	47.56	2,687 73	0 74
Comp. b	8	64 53	2,218.72	0.70
	16	56 04	2,453.22	0 72
Error	40	27.58	2,093.49	0 92
R. block error	56	35 71	2,196.27	0.86
Effective error term		30.71	2,183.30	0.90
Date split	216			
Dates	3	238.69†	323,846.53	111.07†
Dates × reps	21	20 84	2,715 91	1.14*
Dates × variety	24	154.76†	8,381.57†	2.20†
Dates × blocks				
Comp. a	24	34 97*	5,428.37†	1.15*
Comp. b	24	18.33	2,895.70	0.90
	48	26.65	4,162.03*	1.02
Error	120	17.64	2,436.81	0.60
D.R. block error	168	20.22	2,929.73	0.72
Effective error term		18.84	2,648.81	0.65

*Significant at 5 per cent level.
†Significant at 1 per cent level.

Efficiency of whole plot (per cent)	116.00	100.60	95.60
Efficiency of date split (per cent)	107.00	110.60	111.00
Coefficient of variation (per cent)	9.64		1.06
Date L.S.D. at 5 per cent	1.43	16.99	0.26
Date L.S.D. at 1 per cent	1.88	22.46	0.34

Discussion

The 3 x 3 balanced, duplicated lattice design gave a 16 per cent greater overall efficiency on the total plot layout for the original ascorbic acid content and a 7 per cent greater efficiency in the seasonal trend study over a similar randomized plot design. The variation between duplications, blocks, and replications was very small, thus indicating that the field plots were quite uniform.

The major variation was between varieties. The seasonal average ascorbic acid content on a fresh weight basis ranged from 43.39 mg per 100 grams of berries for Missionary to 66.71 mg for Fairmore. The other varieties were intermediate and ranged in a fairly regular progression from Missionary to Fairmore. The average variation in ascorbic acid content for the season was 9.6 per cent of the mean.

The agreement between the ascorbic acid content of the varieties reported here and the results of workers in other states may be seen in Table V.

TABLE V—Comparison of Ascorbic Acid Content of Strawberry Varieties in Mississippi and the Results Reported Elsewhere, Expressed in Milligrams Per 100 Grams of Fresh Berries

Variety	Mississippi	North Carolina	North Carolina	New York State
	Overcash McWhirter	Satterfield Yarbrough (8)	Burkhart Lineberry (1)	Robinson (10, 11)
Fairmore	66.71	64.8	65.97	—
Suwannee	58.06	—	—	68.0
Tennessee Shipper	56.36	—	—	75.0
Klonmore	54.18	—	—	—
Klondike	53.19	38.8	46.30	38 0
Tennessee Beauty	53.18	—	—	75.0
Massey	47.77	—	41.70	58.0
Blakemore	47.68	42.6	32.60	42.0
Missionary	43.39	36.2	46.00	36.0

When considered on a moisture free basis, there is a distinct decrease in the ascorbic acid content of all varieties from the first to the last analysis of the season. This conforms with the reports of Olliver (7).

No correlation was found between the moisture content of a variety and its suitability for shipping. Varieties such as Blakemore and Tennessee Shipper, which have very firm fruits, were among the highest in moisture content. Suwannee, a home garden variety with soft berries, was one of the lowest in moisture content. A significant decrease in moisture content was noted between the first and last harvest dates. The relatively small size of the increment of decrease in average moisture content noted on May 21 was due to light rainfalls on May 19 and 20.

Summary

1. Nine strawberry varieties were grown in a 3 x 3 balanced duplicated lattice design and analyzed for ascorbic acid at weekly intervals for 4 weeks.

2. On a fresh weight basis, the seasonal average ascorbic acid conten of these varieties ranged from 43.39 to 66.71 mg per 100 grams of berries.

3. The varieties ranked from the lowest to the highest seasonal average ascorbic acid content on a fresh weight basis, as follows: Missionary, Blakemore, Massey, Tennessee Beauty, Klondike, Klonmore, Tennessee Shipper, Suwannee, and Fairmore.
4. A significant decrease in ascorbic acid content on a moisture free basis was observed during the season.
5. Significant differences in moisture content of the berries were observed between varieties.
6. The moisture content of the berries decreased during the season.
7. This 3 x 3 balanced, duplicated lattice field layout gave a 16 per cent greater efficiency for the original ascorbic acid content over a similar randomized plot design.

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The Keeping Quality of "Pre-Packaged" Fresh Cranberries[1]

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During the past several years the merchandising of fresh fruits and vegetables has been characterized by a trend toward "pre-packaging". This term is used to denote the packaging of produce in individual consumer-size packages for retail sales. The present investigation was made to obtain information on the keeping quality of fresh cranberries when "pre-packaged". During the past season a considerable volume of cranberries was marketed in this manner.

So far as could be determined no studies have been reported on the keeping qualty of "pre-packaged" cranberres. Thus, in order to better understand the storage or package requirements of cranberries we must turn to work that has been done on the effect of storage on the keeping quality of fresh cranberries.

Since cranberries are living organisms, their respiration and keeping qualities may be impaired if they are packaged or stored under conditions which do not permit adequate ventilation. Shear, Stevens and Rudolph (7) called attention to the spoilage of cranberries caused by insufficient ventilation. Cranberries kept in tight cans or in an atmosphere of carbon dioxide lost their crispness and bright color, became dull red and flaccid, and had a bitter taste. This type of spoilage, which was apparently caused by conditions which checked normal respiration, was designated as smothering. This condition has been found to occur whenever cranberries of good keeping quality are covered with an inert gas, such as carbon dioxide, buried for some time in a big pile of berries, shut up in a tight container, kept under water, or subjected to other conditions which prevent normal respiration. Morse (6) showed that cranberries gave off twice as much carbon dioxide at 50 degrees F, as at 33.8 degrees F, and that the rate doubled again at 68 degrees F.

Esselen and Fellers (1) and Levine, Fellers and Gunness (4) showed that the keeping quality of cranberries tended to parallel the carbon dioxide content and carbon dioxide-oxygen ratio of the internal gases of the fruit. It was indicated that minimum storage losses will occur if cranberries are held at 35 degrees F. Storage losses were reduced from 5 to 10 per cent by keeping the berries at from 35 to 45 degrees F, as compared with storage at 50 to 60 degrees F. Gunness, Franklin and Fellers (3) confirmed previous results with different storage temperatures for cranberries. In addition it was shown that cranberries stored at 60 degrees F had a 2- to 5-per cent greater storage loss than those held at 55 degrees F.

In the case of some fruits, such as apples and pears, considerable success has been realized in the use of controlled-atmosphere storages in which the carbon dioxide content is controlled at levels above the concentration normally found in the atmosphere. Gunness, Franklin and Bergman (2) carried out controlled-atmosphere storage tests

[1]Contribution No. 682, Massachusetts Agricultural Experiment Station.

with cranberries and concluded that this method of storage holds but little promise of success. Even when the carbon dioxide content of the storage atmosphere was as low as 2.5 per cent, greater losses were encountered than occurred in a normal ventilated storage.

Thus, on a basis of studies made on the keeping qualities of cranberries it would appear that cool ventilated storage is desirable. Unlike some other fruits cranberries do not appear to be able to tolerate excessive or abnormal amounts of carbon dioxide in the storage atmosphere. It is obvious that conditions which apply to the commercial storage of cranberries could also be expected to apply to fresh cranberries which are packaged in small consumer-size packages. Cool storage temperatures and adequate ventilation or gas permeability of the package would appear to be desirable.

Experimental

Cranberries of the Early Black variety, obtained from the Massachusetts Cranberry Experiment Station at East Wareham, were carefully sorted by hand to eliminate spoiled and soft berries. The fruit was then packaged in 100-gram portions in heremetically sealed half-pint jars, "grocery store type" Kraft paper bags, 300 MST Cellophane bags, and 240 N Pliofilm bags. The latter two types of packages were

TABLE I—Effect of Storage at Different Temperatures on Keeping Quality of Fresh Early Black Cranberries in Different Kinds of Packages

Storage Period (Wks)	Storage Temperature (Degrees F)	Loss of Weight (Per Cent)	CO_2 Content of Package Atmosphere (Per Cent)	Spoiled Cranberries (Per Cent)
		Kraft Paper Bag		
1	Room	8.0	0.27	14.7
2	Room	19.0	0.96	21.4
3	Room	25.5	0.48	57.6
3	35	1.0	0.51	6.5
6	35	3.0	0.70	14.9
9	35	3.0	0.90	15.5
12	35	4.5	1.29	21.2
15	35	6.5	0.62	26.2
18	35	8.5	1.06	35.5
		300 MST Cellophane Bag		
1	Room	4.0	6.03	17.0
2	Room	7.0	8.73	27.7
3	Room	7.5	11.00	43.9
4	Room	11.0	8.38	57.6
3	35	0.0	1.33	8.0
6	35	1.0	2.53	8.7
9	35	1.5	1.68	16.2
12	35	2.0	1.59	18.4
15	35	3.5	2.58	25.9
18	35	4.5	1.74	27.8
		240 N Pliofilm Bag		
1	Room	4.5	5.84	15.8
2	Room	6.5	2.70	27.2
3	Room	9.0	2.88	27.7
4	Room	9.5	2.31	34.1
3	35	0.0	2.57	5.5
6	35	0.0	3.71	9.5
9	35	1.0	4.01	15.1
12	35	0.5	3.45	17.1
15	35	1.0	2.30	24.7
18	35	1.5	3.09	31.0

heat-sealed, and the Kraft bags were sealed with tape. Sufficient packages of each kind were put up for storage tests at room temperature (approximately 70 to 75 degrees F) and at 35 degrees F.

The tests used to determine the keeping quality were (a) loss in weight, (b) per cent spoilage; and (c) carbon dioxide content of the atmosphere within the package.

The packages were taken from storage and tested in duplicate or triplicate, at intervals of 1 week and 3 weeks, respectively, for those stored at room temperature and 35 degrees F. The degree of spoilage was estimated by separating the spoiled berries and calculating the per cent spoilage on a weight basis.

The carbon dioxide content of the atmosphere within the packages was determined with a modified Blacet-Leighton gas micro-analysis apparatus as described by Lewis (5). A sample of gas from the package was transferred to the apparatus by means of a 10 cc medical syringe. The syringe was first rinsed in the gas by inserting the needle into the package, and drawing the gas in to the bore. This gas was discharged from the syringe. The syringe was then rinsed a second time and a mercury seal within the syringe was made by discharging the rinse into a jar of of mercury from which approximately 2 milliliters were drawn up into the syringe. The needle was again inserted into the package, and the gas which was drawn through the mercury into the syringe, was used as the sample for analysis. This sample was transferred to the holding tube of the apparatus for analysis. Once the package was pierced, a slight positive pressure was maintained on it to prevent the entrance of air.

The results of the above tests are summarized in Table I, and Fig. 1.

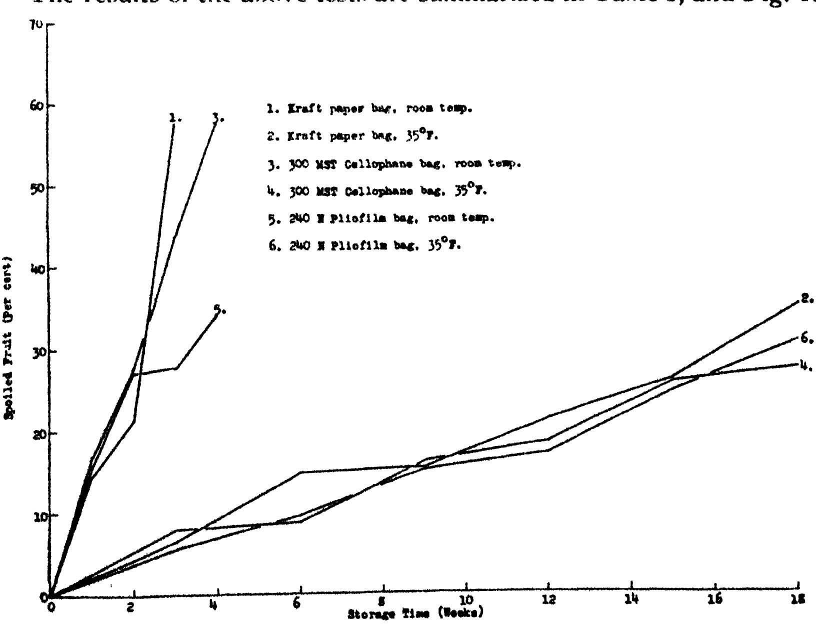

FIG. 1. Effect of type of package and storage temperature on keeping quality of Early Black cranberries.

In addition to the tests with packages of cranberries prepared in the laboratory, storage tests were also made with fresh cranberries packaged under commercial conditions and furnished through the courtesy of the National Cranberry Association and the American Cranberry Exchange. An experimental pack of Howes cranberries was put up in 12-ounce bags which were packed and sealed mechanically. The following kinds of packages were used: (a) 300 LSAT Cellophane; (b) 450 LSAT Cellophane; and (c) a duplex bag consisting of a 300 LSAT Cellophane inner bag and a 300 MSAT Cellophane outer bag. Duplicate lots of each type of container were put up in which two holes approximately ⅛ inch in diameter, were punched in the bags just below the seal to facilitate a better gas exchange between the atmosphere inside and outside the packages. These packages were stored in cartons such as were being used in practice. The results obtained are shown in Table II and Figs. 2 and 3.

TABLE II—Effect of Storage at Different Temperatures on Keeping Quality of Fresh Howes Cranberries Packaged in Different Kinds of Cellophane Bags

Storage Period (Wks)	Storage Temperature (Degrees F)	In Sealed Bags: Loss of Weight (Per Cent)	In Sealed Bags: CO_2 in Package Atmosphere (Per Cent)	In Sealed Bags: Spoiled Cranberries (Per Cent)	In Punctured Bags: Loss of Weight (Per Cent)	In Punctured Bags: CO_2 in Package Atmosphere (Per Cent)	In Punctured Bags: Spoiled Cranberries (Per Cent)
			300 LSAT Cellophane Bag				
1	Room	1.5	4.47	5.1	2.0	3.22	4.6
2	Room	3.4	3.78	30.7	3.8	1.85	28 4
3	Room	5.1	3.36	33.2	4.9	2.70	31.6
4	Room	7.0	3.19	44.9	7.8	2.75	45.3
3	35	0.7	1.71	2.1	0.9	0.71	3.9
6	35	1.2	2 16	7.4	1.3	1.76	4.3
9	35	1.8	1.33	6.5	1.9	1.56	5.0
12	35	2.5	1 27	10.2	2.6	1 02	8.9
15	35	4.1	1.39	12.8	4.4	1.21	12.7
18	35	4.9	2 74	19.9	4.8	1.17	16.9
			450 LSAT Cellophane Bag				
1	Room	1.6	3.88	4.8	2.0	1.80	4.9
2	Room	4.6	9.61	29.0	4.4	5.03	33.1
3	Room	6.2	14.12	37.0	6.0	3.37	36.5
4	Room	7.2	13.17	49.2	7.5	1.91	44.5
3	35	0.9	1.46	5.4	1.2	1.12	2.7
6	35	1.3	1.68	5.2	1.5	1.69	3.3
9	35	2.5	1.30	6.2	2.6	1.27	5.7
12	35	2.9	1 23	9.8	3.1	4.48	9.8
15	35	4.1	1.69	12.8	4.4	3.22	13.0
18	35	5.4	1.95	15.1	5.3	1.47	13.8
			300 LSAT Inner and 300 MSAT Outer Duplex Cellophane Bag				
1	Room	0.7	1.98	3.6	0.4	10.70	4.5
2	Room	1.6	2.95	31.1	1.2	11.81	24.9
3	Room	2.1	2.30	38.9	1.5	7.35	29.1
4	Room	2.8	1.19	44.3	1.9	9.36	44.1
3	35	0.3	1 51	2.1	0.1	3.80	1.4
6	35	0.6	1.96	5.0	0.3	2.18	2.2
9	35	1.2	0.97	7.1	0.6	2.28	4.7
12	35	1.5	0.91	11.4	0.9	1.62	7.6
15	35	1.6	1.28	17.3	1.3	3.45	9.7
18	35	1.9	1.58	24.5	2.5	2.70	17.2

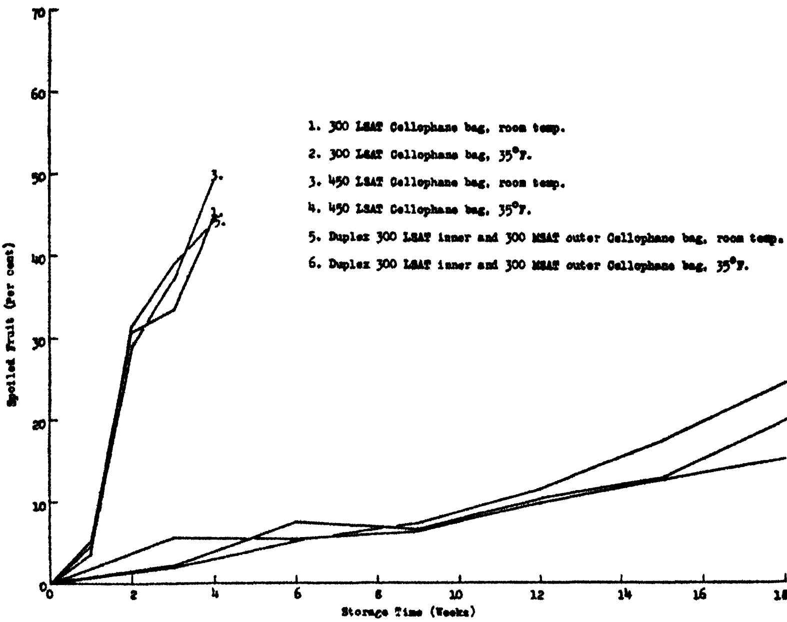

FIG. 2. Keeping quality of packaged Howes cranberries.

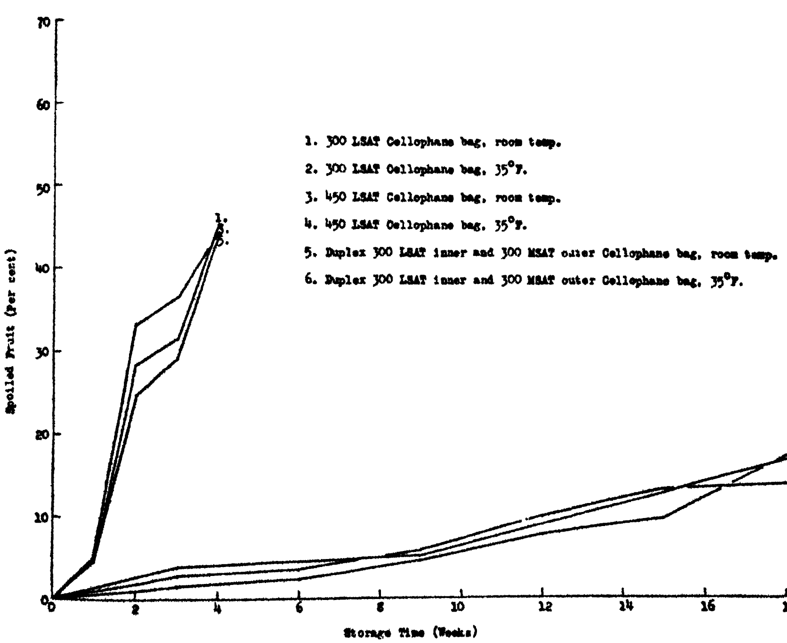

FIG. 3. Keeping quality of Howes cranberries in punctured packages.

Results

Cranberries which were packed in heremetically sealed jars showed almost complete spoilage within a week at room temperature and in 3 to 4 weeks at 35 degrees F. These results are not included in the tables. As may be seen from the experimental data, in all of the packages used the cranberries deteriorated more rapidly at warm storage temperatures than at 35 degrees F. In general the keeping qualities of the cranberries in the different kinds of packages showed the same trend. As might be expected the Kraft paper bags were inferior to the other packages from the standpoint of spoilage and loss of weight. Puncturing the bags had little or no influence on the keeping quality of the cranberries.

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A New Fall Bearing Red Raspberry, Durham — and the Spur Blight Problem

By A. F. YEAGER and M. C. RICHARDS, *New Hampshire Agricultural Experiment Station, Durham, N. H.*

THE coastal area of New Hampshire is characterized by cool summers, cool long, moist autumns, with a closed winter; that is, one where the snow stays on the ground, and a minimum temperature in midwinter of 15 degrees below zero in ordinary years. For red raspberries, this would not be considered a particularly severe climate, nevertheless winter injury ordinarily makes raspberry production unprofitable. In 1940, winter injury studies were started at the University of New Hampshire with C. L. Calahan working on this as a graduate thesis problem. He tried waxes, sprays, covering the plants with mulch, covering the plants with soil, and shading. The only thing that gave beneficial results was soil covering, even this was not very satisfactory. The raspberry fields in spring were spotted by some canes which survived and others which did not. It was noted that more often it was the largest canes which were winterkilled and some of the smaller, weaker ones which survived. It was then noted that on these larger canes were bluish blotches which, however, were only on the surface and did not appear important. Nevertheless, the association between those blotches and winter injury was quite apparent and when examined by plant pathologists, the disease was diagnosed as spur blight, caused by *Didymella applanata.*

Then began careful observations of the spur blight situation. It was found that raspberries at Durham commonly produced well the second year after planting, somewhat less the following year, and after this gave unprofitable crops, and this unprofitable condition is assumed to be related to the heavy infestations of spur blight. Russell Eggert found that evaporation from the stem areas affected by spur blight was much more rapid than from other areas. Since the Horticultural Department was convinced that this was our chief raspberry enemy, it was decided that it, rather than winter injury, should be studied.

In 1944, a considerable raspberry planting was made for the purpose of studying the disease. This consisted of four rows each of Taylor, Latham, and Viking about 400 feet in length. These were sprayed in 1945 basing the treatment on the work of R. F. Suit (1). This consisted of Elgetol as a delayed dormant spray followed by Fermate. In the fall of that year Latham and Taylor were nearly 100 per cent infected, with Viking less but still extremely high and about the same on sprayed and unsprayed plants. In 1947 spur blight was a little less prevalent than the preceding years but still not significantly different on the sprayed plants than on the checks. Therefore, we conclude that, up to the present time, spraying as a control at the University of New Hampshire has not been effective.

While the complete removal of canes in the spring before spores are produced is an effective way of ridding a field of this disease, it nevertheless results in the complete loss of that year's crop; and as soon as the spring fruiting canes are left to produce, disease builds up again.

Since the Viking variety is consistently less affected than the other two varieties grown, the crops are greater. This suggests that it might be possible to develop varieties resistant to the disease. At the present time, however, we know of no immune varieties, hence this approach is not too promising.

Since the removal of canes is effective, it was thought that the development of a raspberry which would produce a heavy fall crop on new shoots and thus avoid skipping one year's crop might be a practical means of approaching this problem. Therefore, breeding work in this direction was started. The commercial varieties of everbearers do not produce a profitable crop in New Hampshire because they bloom so late in the fall that very little fruit is ripened before the first severe frost. Hence the proper approach to the everbearing problem would seem to be earlier blooming varieties and earlier ripening varieties. Many crosses were made between everbearing sorts. All the seedlings produced showed very little promise. The group of plants showing the most promise was one in which the mother parent was Taylor raspberry, a non-everbearing variety. This was pollinated by Nectarberry, a trailing blackberry. Among a small group of this parentage two seedlings began blooming very early and ripened their crop early. One of these was named Durham in 1947. While the seed from which this plant grew was Taylor pollinated by Nectarberry, it is not thought that the Nectarberry actually entered into the genetic constitution of this plant since there are no indications of it.

Durham is very strongly fall fruitful, blossoming on the ends of new shoots which may be as little as 18 inches in length. The blossoms open in early August and the berries begin to mature by August 20. The fruiting area extends back a considerable distance from the tips. The fruit is medium in size, good quality, and very firm. The spring crop from these plants has not been promising. The principal value of the variety would be as a fall bearer. The fall crop has been very much greater on this than on any other variety which has been tested up to the present time at the University of New Hampshire.

Some plants are available commercially, and there should be a reasonably abundant supply by 1950. In the meantime, plants are available from the University of New Hampshire for experiment stations and as foundation stock for nurseries who desire it.

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A Study of the Rest Period in Red Raspberries[1]

By JOHN S. BAILEY, *University of Massachusetts, Amherst, Mass.*

UNTIL quite recently little was known about the rest period in red raspberries. They were assumed to have a rest which was probably short and which might have some relation to cold injury. Bradford's (2) observations on the growth of raspberries in Missouri suggested that the rest might end as early as October in that state. Vaile (6) observed that in Arkansas the rest period of brambles varied, but was usually completed in January. The buds of varieties which suffer winter injury most often seemed to have very short rest periods, according to Van Meter and French (7). Colby (5) stated that experience indicates that cold spells at 0 degrees to +10 degrees F might break the rest so that the buds start to develop during subsequent short periods when the temperature reaches about 50 degrees F and are thus made susceptible to cold injury.

Later Bailey *et al* (1) reported that the rest period for raspberries is very short, ending in early December. Brierley (3) and Brierley and Landon (4), working with the Latham variety in Minnesota, found that it is in its deepest rest in mid-October, comes out of the rest gradually, and is completely out in early December at the time of the first zero temperatures; that the ending of the rest results from the cumulative effect of a certain number of hours below about 41 degrees F; and that severe freezing weather appears to contribute to the breaking of the rest.

These experiments were started in the fall of 1944 to find out (a) what is the intensity and duration of the rest period in red raspberries; (b) whether there are varietal differences in regard to rest, particularly between cold resistant and tender varieties; and (c) what relationship exists between the rest and cold resistance.

MATERIAL AND METHODS

The six varieties, Chief, Latham, Milton, Taylor, Marcy and Washington, were used in these experiments. Chief and Latham were selected because of their cold resistance, Marcy and Washington because of their lack of it, and Milton and Taylor as being roughly intermediate in hardiness. From November 1 to late December or early January five canes of each variety were brought into a greenhouse at 2-week intervals during 1944 and at about weekly intervals during 1945 and 1946. These canes were placed in vases with enough water to cover the butt ends. The usual procedure of cutting off the base of the canes and changing the water frequently to prevent plugging was followed. The greenhouse temperature was 60 degrees F during the night but varied considerably during the day. Records were kept of the number of days from the time the canes were brought in until the buds showed green tips.

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[1]Contribution No. 658 of the Massachusetts Agricultural Experiment Station.

Results

The results are shown graphically in Figs. 1, 2, and 3. In a number of cases not all the canes of a variety had buds start, even though they were left in the greeenhouse several weeks after buds on the other canes of the same lot had started. Where this happened, numbers in parenthesis on the graphs give the number of canes on which buds did start.

Discussion

The graphs show several interesting things. The variety Chief was the slowest to start growth in all three years. There was a period

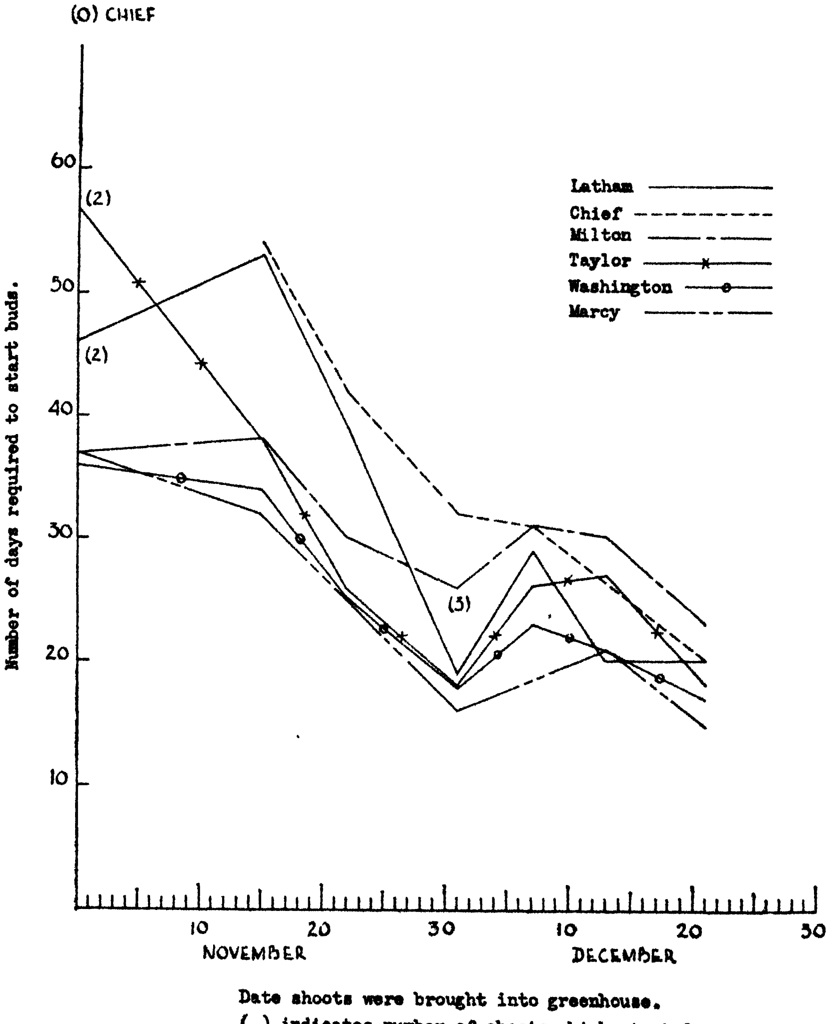

FIG. 1. The number of days required to force the buds on raspberry canes into growth in the greeenhouse in 1944.

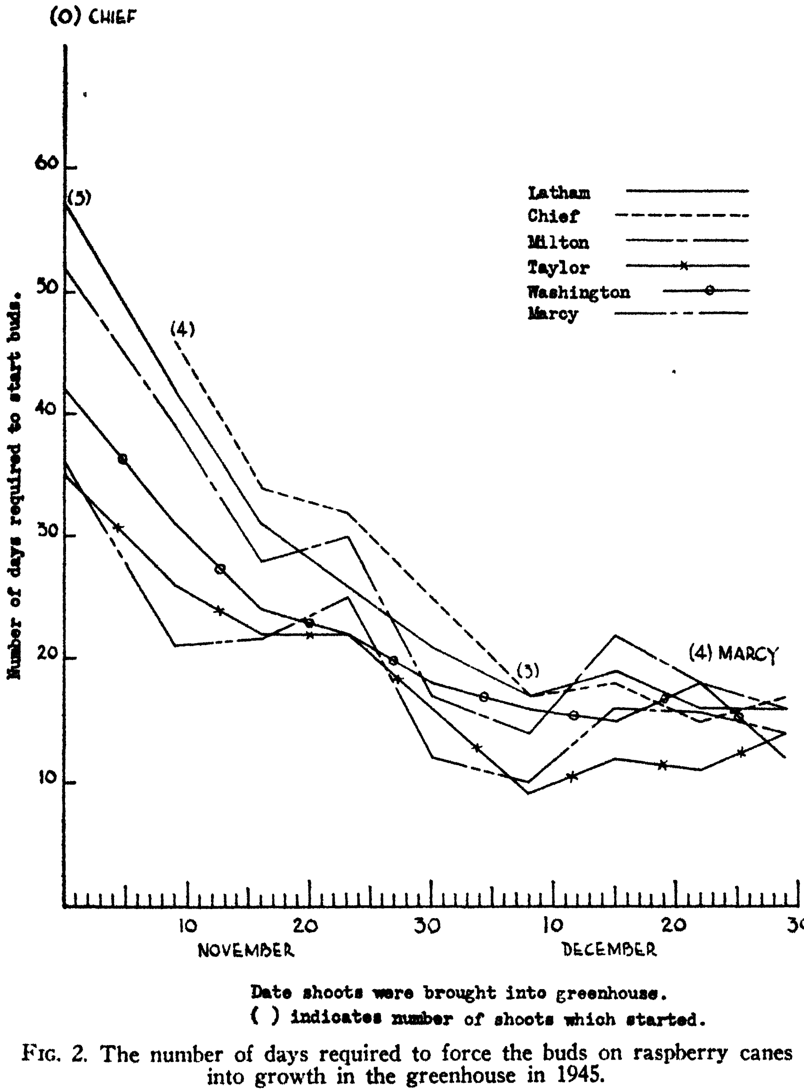

FIG. 2. The number of days required to force the buds on raspberry canes into growth in the greenhouse in 1945.

during which the canes could not be started into growth. These facts show that it was in the deepest rest of the six varieties.

Latham, in 1944 and 1945, follows rather closely, at least during the early part of the period, the trend of Chief although it appears not to have been in quite so deep a rest. On November 1, 1944, the buds on only two canes started. If the number of days to start of all five canes had been averaged in determining the point on the graph, then the curve would have to go off the graph towards infinity as would the curve for Chief where none started. Even in 1946 which was an unusual season, the behavior of Latham came closer to parallel-

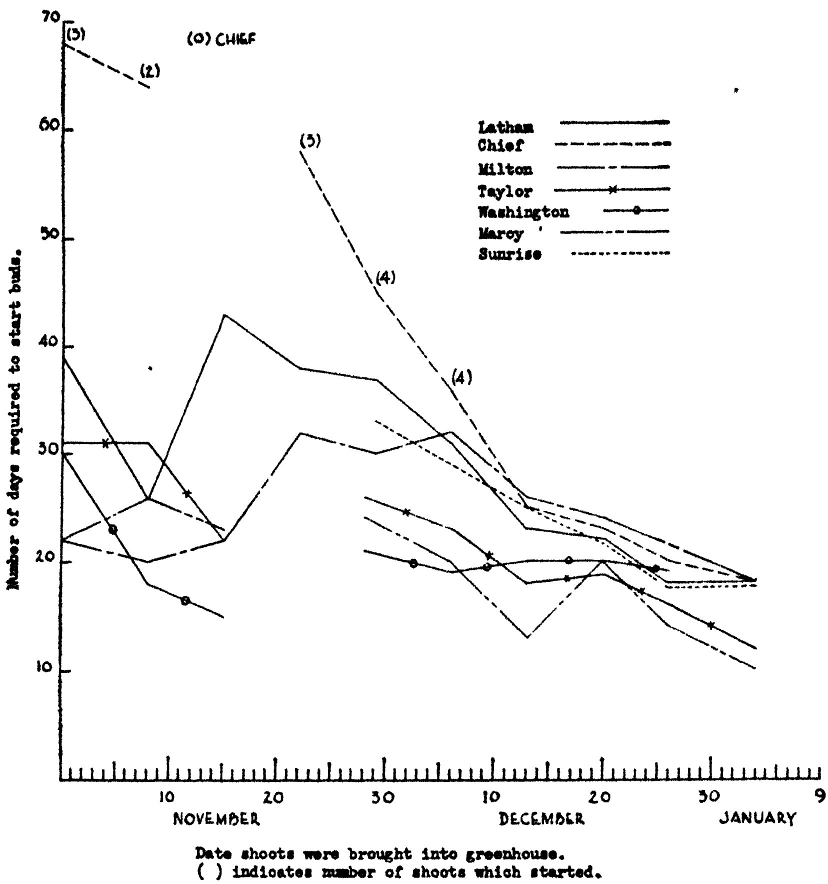

FIG. 3. The number of days required to force the buds on raspberry canes into growth in the greenhouse in 1946–47.

ing that of Chief than any other variety. Therefore, Latham appears to have been in nearly as deep rest as Chief during 1944 and 1945 but came out of it a little faster.

Since Marcy and Washington could be started into growth much more easily than Latham or Chief until the rest period was over, they were not in as deep a rest and in most cases the rest did not last as long. Taylor appears to have been in as deep rest as Latham on November 1, 1944 but came out of it more rapidly. In the other two years it was not in so deep a rest. Milton could be started into growth more easily than Latham during November or until the rest was over. Taylor and Milton showed behavior which at times resembled Chief and Latham and at others Marcy and Washington. In 1946 canes of Sunrise, a new variety which is supposed to be cold resistant, were brought in during the latter part of the period. Their behavior closely paralleled that of Latham.

The rest period appears to end early in December in normal years. With the exception of Chief, and possibly Milton, it was over December 1 in 1944. In 1945 it was over December 8, as indicated by the flattening out of the curves.

The year 1946 is of special interest because of unusual weather conditions. The last frost occurred on May 4 and the first frost on October 22, giving a frost-free season of 171 days. If we accept the local weather bureau's statement that no killing frost occurred until November 13, this gives a frost-free season of 193 days. The frost-free periods for 1944 and 1945 were 138 and 163 days, respectively. The deepest rest in 1944 and 1945 was on or before November 1. In 1946 Chief, Latham and Milton did not reach their deepest rest until November 15 or later. This indicates that the length of the season affects the time at which deepest rest is reached, as suggested by Brierley and Landon (4). However, the deepest rest was reached latest in the longest season which is contrary to Brierley and Landon's (4) results.

It is also interesting to note that even in this abnormally long season Chief went into so deep a rest that the buds failed to start, whereas none of the other varieties went into such a deep rest.

The data indicate, as suggested by Brierley and Landon (4) for the variety Latham, that the ending of the rest is brought about by the effect of the accumulation of hours of temperature below the threshold for hardening which is about 41 degrees F. If periods of low temperature are a factor in breaking the rest, as suggested by Colby (5) and Brierley (3) and Brierley and Landon (4), they are not such a potent one as temperature accumulation, at least under field conditions. On November 24, 1944, a temperature of 18 degrees F occurred and yet there was no sudden break in the curves. A temperature below 20 degrees F did not occur again until December 2 when it went down to +12 degrees F. On each of the next 5 days the temperature went to 20 degrees F or below, but resulted in no shortening of the time required to start bud growth. Even +1 degree F on December 19 and −5 degrees F on December 20 had no more than a minor effect on the starting of buds on canes brought in December 21. Similar instances of the minor effect of periods of low temperature could be pointed out for the years 1945 and 1946.

It is also interesting to note that varieties which are cold resistant, such as Chief and Latham, go into a deeper rest and come out more slowly than tender varieties such as Marcy and Washington. This suggests a relationship between intensity and duration of winter rest and cold resistance. This relationship is obscure and an explanation must await further evidence. If it is a causal one, two possibilities are suggested: (a) The development of the rest period accelerates the hardening process and (b) the rest period, until it is over, retards the dehardening process.

Summary

1. The rest period of red raspberries, at least in a normal season, is short, ending in early December.

2. The red raspberry comes out of the rest gradually.
3. The ending of the rest is brought about by the effect of the accumulation of hours of temperature below about 41 degrees F.
4. Periods of low temperature play a minor part in ending the rest.
5. Hardy varieties, such as Chief and Latham, enter a deeper rest and come out more slowly than tender varieties like Marcy and Washington.
6. The variety Chief is outstanding in its ability to enter deep rest and come out slowly. This suggests the desirability of using it as a parent in breeding to impart such qualities to new varieties.

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A Study of the Effects of a–Naphthaleneacetic Acid on Prolongation of Rest in the Latham Raspberry[1]

By J. S. McCartney, *University of Minnesota, St. Paul. Minn.*

Winter-killing in the Latham raspberry is rather common throughout the United States and Canada, and evidence seems to point to the short rest period and the warm days in winter followed by cold as being one of the contributing combinations. Bailey *et al* (1) showed that the rest period is over by late November, or early December, in Latham under Massachusetts conditions. Colby *et al* (4) believes that in Illinois, Latham is often damaged by alternating cold and warm spells. Brierley and Landon (3) showed that there is a gradual lessening of the intensity of rest during late October and November and that by mid-December buds will show green at the tips after about 8 days in the greenhouse. Leslie (7) stated in relation to winter injury, "the canes may survive, but the flower buds be killed". Bradford (2) suggested that the rest period of the raspberries in Missouri is easily broken and may be completely over by late October.

Brierley and Landon (3) have further pointed out that although cold resistance develops under exposure to cold, this also breaks the rest. When the rest is broken and the canes are exposed to warm temperatures followed by cold, there is injury to the buds and the canes. This injury may be due to loss of cold resistance without growth starting, or may be due to loss of cold resistance because growth starts.

Prolongation of the rest period has been accomplished with certain plants in common storage. Guthrie (5) found that he could inhibit the growth of buds of potato tubers with the vapor of the methyl ester of a–naphthaleneacetic acid. Marth (8), working with roses, found that a number of different growth-regulating substances, including a–naphthaleneacetic acid, would inhibit the growth of buds from 40 to 60 days in common storage. He also noted that the inhibitors had to be applied to the buds to get the desired effect. Strong concentrations caused damage and weak concentrations decreased the rest period in storage. Hitchcock and Zimmerman (6) found that potassium naphthaleneacetate, used under orchard conditions, was effective in inhibiting the growth of fruit buds in the spring. Applications were made in late summer and early fall. Early applications of weak concentration were more effective than late applications of strong concentration. They also noted that vegetative buds were delayed more than flower buds.

The object of this study was to determine what effect a–naphthaleneacetic acid might have on the Latham raspberry with particular reference to the rest period, loss of cold resistance and low temperature injury.

Materials and Methods

Two plots of Latham raspberry were used in this study. One plot,

[1]Paper No. 2407 of the Scientific Journal Series of the Minnesota Agricultural Experiment Station.

located at the University Farm, consisted of vigorous, healthy plants with canes averaging about 5 feet in length at the end of the growing season. The other plot, located at the University of Minnesota Fruit Breeding Farm, Excelsior, although vigorous and free from disease, consisted of plants which were noticeably set back in their growth. A freeze in mid-May had killed most of the new growth to the ground, and a hail storm in June bady damaged the second growth of canes. By the end of the growing season these canes were only 3½ feet high.

The a–naphthaleneacetic acid was applied on certain dates and at various concentrations as shown in Table I. A 4-gallon knapsack sprayer was used, and spraying was limited to half the canes in each hill, by covering the remaining canes with water-proof cloth. These canes were used as controls.

TABLE I—INJURY TO LATHAM RASPBERRY LEAVES AND CANES DUE TO a–NAPHTHALENEACETIC ACID

NAA (Ppm)	Date Sprayed	Tip Curl (Days)	Leaf Drop (Per Cent)	Tip Dieback (Inches)	Cane Killing (Per Cent)
1600	Aug 1	1	80–100	4–18	75–100
1600	Aug 15	1	80–100	4–18	80–100
800	Aug 1	1	80–100	4–18	25–35
800	Aug 15	1	80–100	4–18	25–75
800	Aug 31	None	50–75	0–8	15–20
800	Sep 12	None	25–50	None	None
400	Aug 1	1	50–75	0–4	None
400	Aug 15	1	50–75	0–12	None
400	Aug 31	1	25–50	0–4	None
400	Sep 12	None	10–20	None	None
200	Aug 31	None	20–40	None	None
200	Sep 12	None	10–20	None	None
100	Aug 31	None	None	None	None
100	Sep 12	None	None	None	None
50	Aug 31	None	None	None	None
50	Sep 12	None	None	None	None
25	Aug 31	None	None	None	None
25	Sep 12	None	None	None	None

INJURY CAUSED BY a–NAPHTHALENEACETIC ACID

As extensive injury to leaves and cane tips followed the first applications, records were kept of the nature and extent of this injury. In order to be sure this injury was not due to the alcohol solvent for the NAA, a check spray was made up using the necessary amount of alcohol, but no injury followed this treatment. As recorded in Table I, injury was manifest by leaf-curl, tip-killing of canes, leaf fall, and cane killing with some of the stronger concentrations. This injury seemed to follow a fairly regular pattern. With the stronger sprays 1600 and 800 ppm, applied early in the fall, there was an immediate response. During the first 4 days after spraying, leaves at the tips of the growing canes would roll up and the tips bend over as if wilted. Within a week, leaves all over the canes began to turn yellow and fall, leaving about ½ inch of the petiole. By this time, tips of some of the canes were killed. In several cases, particularly when higher concentrations were applied in early August, the canes were eventually killed to the ground. As a result of this injury following use of the NAA it was evident by mid-September that many of the canes were not developing the red-brown coloring, which is associated with maturity.

It can be concluded that concentrations above 800 ppm cause too much injury to be of any value, and that concentrations between 200 and 800 ppm are of doubtful value due to excessive leaf fall, especially when applied early in the fall. When sprays are applied in late fall, there is little apparent injury, and these might be of real value, since growth is almost completed and spraying will cover all buds, which earlier treatments will not do.

Effect of NAA on Rest Period

In order to determine the effect of various spray treatments in prolonging rest, samples of canes from all treatments were collected on December 16 and February 15. These samples were placed in galvanized pails with enough water to cover the cut ends. This water was changed at weekly intervals, and new cuts were made on the butt ends to eliminate clogging of the vessels by bacteria, etc. The canes were examined daily to note bud activity, and the data in Table II show that there was no definite prolongation of rest due to NAA, except with concentrations which also severely injured the canes.

TABLE II—Effect of a-Naphthaleneacetic Acid on Prolongation of Rest Period in the Latham Raspberry

Concentration (Ppm)	Date Applied	Dates of Sampling: December 16	Dates of Sampling: February 15
		Prolongation of Rest Beyond Controls (Days)	
1600	Aug 1	9	All dead
1600	Aug 15	8	All dead
800	Aug 1	5 to 13	6
800	Aug 15	7 to 12	6
800	Aug 31	4 to 9	2 to 6
800	Sep 12	1 to 12	—
400	Aug 1	0 to 14	6
400	Aug 15	1 to 9	3 to 6
400	Aug 31	1 to 5	0 to 6
400	Sep 12	4 to 9	—
200	Aug 31	0	0 to 1
200	Sep 12	0 to 8	—
100	Aug 31	0	0 to 1
100	Sep 12	0 to 5	—
50	Aug 31	0	0
50	Sep 12	0 to 3	—
25	Aug 31	0	0
25	Sep 12	0 to 1	—

Effect of NAA on Cold Resistance

On January 22 samples of the 400 and 800 ppm treatments applied on September 12 and controls were collected and divided into seven lots. These lots were thawed at 45 to 50 degrees F for periods ranging from 2 to 14 days and then frozen slowly to 0 degrees F, and held at this later temperature for 8 hours. The canes were thawed slowly and placed in a cool greenhouse. No growth had started at the end of 6 weeks in any of the canes, including controls, and sectioning of the buds showed them all to be dead. While the treatment may have been too severe, it is believed that NAA had no effect on the rate of loss of cold resistance of buds in the Latham raspberry. While these canes were killed at 0 degrees F, similar samples which had not been pre-

heated to 45 to 50 degrees survived temperatures as low as —50 degrees F.

At the same time similar lots, including controls were frozen under controlled conditions for 8 hours at temperatures between —20 and —50 degrees F. These temperatures could be controlled within plus or minus ½ degree, except at —50 degrees F where the temperature was accurate within plus or minus 1½ degrees F. While Scott and Cullinan (9) have shown that temperature change should not exceed 5 degrees an hour with the peach, this practice was not used in the present studies due to lack of proper equipment. Thus canes frozen at 0 degrees F when collected in the field were lowered to —20 degrees F in 15 minutes, or to —50 degrees F in 1½ hours. In this study the rapid drop in temperature was probably very injurious, however, the results obtained are interesting and provide information for further studies. These data are presented in Table III. It will be noted in this table, under general vigor, that although the controls were uniformly vigorous, and seemed to be injured only slightly, vigor of the sprayed canes declined markedly at the lower temperatures. If the NAA treatments caused injury, which in the field was only evidenced in these lots by leaf fall, this would explain the lessened vigor, and might even explain the delay in bud activity of the treated material.

TABLE III—Cold Resistance of Latham Canes Sprayed With 400 and 800 Ppm of NAA Under Controlled Low Temperatures, Compared With the Unsprayed Control Canes

	Temperatures (Degrees F)											
	−20	−30	−40	50	−20	−30	−40	−50	−20	30	40	50
	Buds Started (Days)				Buds Started (Per Cent)				Growth Vigor*			
Control (not sprayed)	7–10	7–14	9–16	8–12	80	40	30	20	4	5	3	4 (1)†
400 ppm	11–13	11–22	11–20	12–23	80	30	20	10	4	3	2	2 (2)
800 ppm	8–13	17–20	15–21	12–20	60	20	10	10	3	1 (1)	2	2 (3)

*Based on score 1—weak; 5—vigorous.
†( ) Number of canes dead in each five cane sample.

Summary and Conclusions

The data indicate that a-naphthaleneacetic acid has little value in prolonging the rest period of the Latham raspberry. As concentrations, strong enough to give some indication of prolonged rest, caused injury, it is questionable whether prolonged rest or injury was observed.

Cold resistance is lost very rapidly at 45 to 50 degrees F and NAA has no effect in slowing the rate of loss of cold resistance.

Since injury to treated canes was more noticeable after exposure to controlled low temperatures, it is probable that this injury was due directly to the NAA treatment.

The ultimate cold resistance of the Latham raspberry is definitely somewhere below —50 degrees F, or sufficient for most purposes, provided cold resistance is not lost.

Benefit from any prolongation of rest is of doubtful value, unless such treatment also retards the rate of loss of cold resistance upon exposure to warm temperatures.

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A Note on the Inheritance of Flower Type in Muscadine Grapes

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In 1917 both Dearing (2, 3) and Detjen (4) reported the production of functionally perfect-flowered muscadine grapes which made the use of non-fruitful male vines to pollinate the functionally pistillate ones unnecessary.[1] After the first vines of this type were obtained, a knowledge of the inheritance of this character became very important. Detjen (4), after crossing pistillate and perfect-flowered types, reported a sex ratio of 1 perfect to 1.07 pistillate vines in a progeny of 1424 which included 45 plants of undetermined sex. Dearing (2) from similar crosses reported 59 perfect, 36 pistillate, 4 staminate, and 34 undetermined; and in another progeny, 30 perfect and 24 pistillate plants. Dearing (3) also reported a progeny of 5 perfect-flowered plants as the result of selfing a perfect-flowered vine.

From 1938 to 1940 several of the better perfect-flowered seedlings from the earlier work of the United States Department of Agriculture were planted at the United States Horticultural Field Station, Meridian, Mississippi. These seedlings were progeny of standard pistillate varieties pollinated by the perfect-flowered type and therefore they were expected to be heterozygous for the perfect-flowered character. Breeding for better perfect-flowered varieties was initiated in 1941. Individual records were kept on the seedlings and all vines showing pistillate or staminate flowers were discarded as soon as they blossomed. Flower type is easily determined from the fact that the stamens of the pistillate type are short and reflexed, whereas those of the perfect and staminate type have long filaments and are erect. In the staminate flowers the ovaries are small and abortive whereas in both pistillate and perfect flowers they are well developed.

Table I summarizes the flower types that resulted from crossing the pistillate varieties with perfect-flowered selections. All seedlings were at least 4 years old and had been in the vineyard 3 years or longer so that the record on flower type was complete for the entire population. Detjen (4) has shown that the staminate and perfect types blossom at an earlier age than the pistillate types, so that a record based on flower type of young vines results in an erroneous sex ratio.

For the total number of vines, the proportion of pistillate to perfect-flowered ones was approximately 1 : 1, the same as observed by Detjen (4). In making his crosses Detjen used a single perfect-flowered vine that varied greatly in its ability to set fruit. In some years it set fruit freely while in other years it was entirely barren. The pollen was always fully fertile and apparently the transmission of the character for perfect flowers was unaffected by the variable ability to set fruit. No male (staminate) vines were observed by Detjen in the hybrid prog-

[1]The flower types will hereafter be referred to as perfect, pistillate, and staminate according to the way in which they function. They have been adequately described by Detjen (4).

TABLE I—FLOWER TYPES RESULTING FROM THE POLLINATION OF PISTILLATE-TYPE MUSCADINE GRAPES BY THE PERFECT-FLOWERED TYPE AT THE UNITED STATES HORTICULTURAL FIELD STATION, MERIDIAN, MISSISSIPPI

Seed Parent	Undetermined, But Not Male*	Perfect	Pistillate	Male
Scuppernong	12	97	75	3
Thomas	1	32	40	6
James	—	19	11	—
Mish	1	16	34	4
Topsail	1	40	52	1
Hunt	3	57	47	10
B-4 12	1	108	103	—
4035	—	5	—	—
4037	—	4	3	—
B-6 112	–	3	—	—
Total	19	387	365	24

*These vines bore fruit, but the flower type was not determined.

eny of this perfect-flowered plant, but two staminate vines out of a progeny of six were produced when it was self-pollinated. As noted before, Dearing (2) reported four male plants in a progeny of 133 vines from crossing the pistillate and perfect-flowered types. The ratio of perfect to pistillate plants resulting from crossing these two flower types by both Detjen and the author agrees with that expressed by the theory of sex inheritance of bunch grapes as advanced by Oberle (5). A summary of the data in Table I by pollen parents instead of by seed parents has indicated no genetic difference in their sex determining factors.

Oberle's theory of sex inheritance in bunch grapes does not allow for the production of staminate seedlings when crosses are made between pistillate and perfect-flowered types. Since the muscadine grapes have one more pair of chromosomes than the bunch grapes, there may also be a difference in the factors that determine sex. In all cases where male plants did result from crossing the pistillate and perfect types they occurred in such small numbers that they could easily have been considered to be due to those accidents that plague all plant breeders in attempting to do accurate work. Some of these result from accidental insect pollination, contamination of the pollen used, and mixture of the seed or seedlings in handling. However, this small number of male plants should not be ignored, for similarly, a very small percentage of male seedlings has occurred in red raspberry breeding (1, 6). More records on flower type of muscadine grapes are needed, particularly as a result of selfing, of crossing the perfect-flowered type, and of using pollen from staminate vines on the perfect-flowered type.

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Control of Grape Root-Rot in Solution Culture

By W. O. WILLIAMS and WILLIAM B. HEWITT, *University of California, Davis, Calif.*

ROOT-ROT developed to such an extent in solution culture during investigations on mineral nutrition of *Vitis vinifera* grapes (1) that most of the comparisons became meaningless. Some vines died during the experiments. In order that these nutrition studies might be continued, it became necessary to determine the cause of the root-rot and develop a remedy.

Variations in the mineral concentration of the water culture were unsuccessful in overcoming the root decay. Chapman and Brown (2) found that root-rot of citrus due to *Thielavia basicola* could be controlled by maintaining the pH at 3.5 or by keeping the phosphate concentration at deficiency levels in the nutrient solution. These techniques did not result in noticeable improvement of the grapevines grown in solution culture. The constant attention required for close pH control did not encourage extended experimentation in this direction.

Excessive root-rot during midsummer indicated that the relatively high temperature of the culture solution at that time might have been an important factor in its development.

Water-bath type of temperature-control equipment[1] was used to determine the effect of temperature on this form of root decay. Vines were grown in 10-liter containers which were immersed in different water baths, maintained at 45, 55, 65, 75, 85, and 95 degrees F. Grapevine roots developed most rapidly at 95 degrees F, and they also rotted most rapidly at this high temperature. The same form of rot was found on the roots growing at the lower temperatures. The severity of root-rot appeared to decrease with decreasing temperatures. Nevertheless, growth of the vines at the lower temperatures was not satisfactory.

Three dormant vines were treated for ½ minute in 500 p p m of sodium hypochlorite, rinsed thoroughly in running tap water, and then placed in clean tanks of culture solution held at 95 degrees F. Five weeks later these vines were growing vigorously. Similar untreated vines placed in clean tanks of solution culture at the same time and at the same temperature had all died at the end of 5 weeks. Also vines with but few root cankers taken from cooler tanks died shortly when placed in contaminated solution held at higher temperatures.

A species of Pythium fungus was consistently isolated from cankers on roots of vines grown at the different temperatures. The fungus was cultured on standard potato dextrose agar for 7 days. The cultures were minced, and a suspension placed in solution culture containing rooted vines free of root-rot. After 10 days, cankers showed on the roots of these vines, and the same organism isolated from these lesions.

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[1]Professor E. L. Proebsting courteously extended the use of the equipment for temperature control which he had utilized in his studies of the effect of various environmental temperatures on the devlopment of roots of deciduous trees (3).

The process was repeated sufficiently to determine the pathogenicity of the organism. The fungus causing this form of root-rot was tentatively identified as *Pythium oligandrum* Drechsler by John T. Middleton.[2]

A search was conducted for some fungicide that would serve in solution culture to minimize the development of root-rot and that would not interfere with vine root growth. The approximate concentration, of possible fungicides, necessary to inhibit the growth of *Pythium oligandrum* in culture solution was determined as follows: small discs $^3/_{16}$ inch in diameter were cut from the margins of a 1-day-old culture of *P. oligandrum* grown on potato dextrose agar; three discs were placed in a petri dish with 25 cc of the grape culture solution containing the desired concentration of fungicide to be tested; they were incubated for 24 hours at 86 degrees F and then the radius of fungus mycelium growth measured; tests of each concentration of fungicide were run in triplicate, and the average radial growth of fungus from the nine discs was used as an index of toxicity. On the basis of these tests the following materials were selected for trial in preventing root-rot of the grapes in water-culture solution: Fermate (ferric dimethyldithiocarbamate); Isothan Q15 (lauryl isoquinolinium bromide); Isothan Q 4 (lauryl pyridinium bromide); Lignasan (ethyl mercury phosphate); and Semesan (hydroxymecurichlorophenol). The chemicals were tested at concentrations of 10 and 50 p p m and each replicated three times. Six tanks were maintained as controls.

Three vines, one each of Dogridge *(Vitis champini)*, Ribier, and Muscat of Alexandria *(V. vinifera)* were grown in tanks containing 9 liters of solution. Various salt solutions were added to each tank so that the initial concentration in parts per million approximated 70 N as NO_3 nitrogen, 30 N as NH_4, 18 P, 130 K, 112 Ca, 45 Mg, 1 Fe, 0.054 Zn, 0.036 cu, 0.56 Mn, 0.06 Mo, and 0.5 B. The alkaline tap water utilized furnished the magnesium and boron. Ferrous sulfate or ferric citrate was added as necessary to suppress iron chlorosis. The pH was adjusted with sulfuric acid solutions to the range 5.5 to 6.5 once a week. All tanks were maintained at 90 ± 3 degrees F in order to favor the development of root-rot.

The initial root growth was satisfactory only in the untreated controls and in the tanks wherein the 10 p p m of Fermate was utilized. Pythium cultures, diluted and broken up in a Waring blendor, added to the tanks produced no evident root cankers in the treatment tanks, but the roots of the controls were badly rotted. There seemed to be no marked differences in the susceptibility of the three varieties of vines. The organic mercury compounds caused considerable distortion in root growth.

Fermate was selected for further trials because the roots of the vines growing in solutions containing this material were most nearly normal. Four sets of vines have been grown in the tanks with six vines in each treatment; one series of tanks received 2½, 5, and 10 p p m

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[2]John T. Middleton, Assistant Plant Pathologist in the Experiment Station, Citrus Experiment Station, Riverside, California.

each, added every week and another series, 5, 10, and 20 p p m each, added every 2 weeks. Besides these six treatments comparable check vines were grown without fermate additions.

The first set consisted of 1-year-old vines variety Flame Tokay which were moved directly from the vineyard nursery into clean containers. After 12 weeks the shoot growth indicated a markedly favorable result from the 2½ and 5 p p m of fermate supplied once a week (Table I). The higher concentrations all resulted in less top growth than in the control lots, because the former were apparently somewhat toxic to vine growth and the untreated vines made considerable growth prior to serious root infection.

TABLE I—Green Weights of Grapevine Growth Expressed as Per Cent of Checks

Lot	Parts Per Million of Fermate	Added Weekly				Added Every 2 Weeks		
		0	2.5	5	10	5	10	20
I	Tokay shoot growth Jan 24 to Apr 22	100	146	191	37	90	18	27
III	Thompson Seedless Jun 28 to Sep 5	100	182	186	76	88	118	69
IV	Thompson Seedless Sep 16 to Dec 11	100	315	174	135	129	248	231
	Thompson Seedless root growth Sep 16 to Dec 11	100	494	310	261	224	358	350

A second set, which consisted of Thompson Seedless vines placed in the nutrient culture in midsummer, developed root-rot lesions on all vines, and successful growth was not obtained even in cultures treated with fermate. These young vine rootings had been stored in moist shavings at 35 degrees F for 4 months. Inspection of the roots of similar vines held in storage for future use showed that many of the roots had large necrotic cankers, and others were mostly dead. The cause of these root cankers was not determined. All subsequent lots of vines were treated with Ceresan and the roots cut back to healthy tissue.

The third lot consisted of Thompson Seedless vines which had been stored at 35 degrees F for 5 months. These vines were treated with 833 p p m of 5 per cent ethyl mercury phosphate for 6½ minutes and placed in the culture solutions after partial drying. Although the above treatment did not prevent the further development of cankerous areas on the roots, the vines grew sufficiently to continue the experiment.

In this lot of vines the subsequent top growth, as well as the condition of the roots, indicated an improvement of those receiving fermate. This was particularly evident in the cases of weekly applications with 2½ and 5 p p m of fermate (Table I).

The markedly better results from the weekly additions suggested a study of the variation of toxicity of the fermate in the culture solutions with time. The toxicity of the culture solutions to *Pythium oligandrum* was determined in a manner similar to that previously described for testing the toxicity of fungicides. Samples were taken from the culture solution tanks for these tests at 2-day intervals. From the results of these tests as shown in Table II, it appeared that 6 days after the fermate addition the fungicidal activity at the 4-day period as compared to that of 2 days after the addition possibly results from an increased

TABLE II—AVERAGE GROWTH OF *Pythium Mycelium* FROM AGAR PLUGS FLOATED ON FERMATE-TREATED CULTURE SOLUTIONS AS PER CENT OF GROWTH ON UNTREATED SOLUTIONS

Treatment (PPM Fermate Added)	Days After Addition			
	2	4	6	8
2.5	85	60	70	90
5	43	35	66	68
10	35	25	42	40
20	5	0	20	35

effectiveness of the fermate as the solutions become neutral or slightly alkaline or may be due to a more effective action of a decomposition product of the fermate.

The fourth lot of Thompson Seedless was treated with ethyl mercury phosphate as before except that a 10-minute dip was employed. The comparative figures of root and top growth for this lot of plants as given in Table I indicate a fairly parallel development of top and roots. The tendency for the untreated controls to develop good root growth which later dies off is reflected in the larger differences occurring between the root weights than between top weights.

DISCUSSION

The performance of vines growing in solution culture with fermate at 2.5 p p m approached in some cases exceeded that of plants in higher concentrations even though the former was less toxic to the growth of *Pythium oligandrum*. It appears probable that the relatively few infections which occurred in the low concentrations of fermate may have been due to its toxic effect upon the mycelium inhibiting normal sporangium and swarm spore production, or it may have been toxic to the swarm spores if such were produced. High concentrations of fermate, 10 and 20 p p m, were more toxic to mycelium growth and apparently more effective in checking root-rot even under conditions of heavy inoculum; but their toxicity to the plant, evidenced by abnormal root growth, overbalanced the fungicidal value.

Five parts per million of fermate applied weekly to the hitherto unsuccessful cultures mentioned in the introduction has resulted in growth of Thompson Seedless vines, which has markedly exceeded the growth of similar 2-year-old vines in the field soil under the same climatic conditions.

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Magnesium Injection in Muscadine Grape Vines[1]

By W. L. Lott, *North Carolina Agricultural Experiment Station, Raleigh, N. C.*

Certain varieties of muscadine grape *(Vitis rotundifolia)* are so frequently subject to a chlorosis of the leaves in late summer that this phenomenon has apparently been accepted by some as a varietal characteristic. Thus, Dearing (4) describes the variety James "The leaves are cordate, nearly as broad as long, medium sized, with serrate margin; in late summer they have a mottled yellow and green appearance". Chlorosis, although not restricted to certain varieties, has been observed most frequently in James and Hunt varieties, and less frequently in Scuppernong.

This chlorosis, shown in Fig. 1, appears in August when the fruit is approaching full size, and becomes most pronounced at harvest time. A pattern is formed in the leaf wherein the primary veins and neighboring interveinal tissue remain green, while the margins and the tissue most remote from the veins become pale green to yellow. Such a pattern develops first in the older or basal leaves and progresses outward along the shoot in the younger leaves as the fruit approaches maturity.

Fig. 1. Leaves of muscadine grape showing (left and middle) late summer chlorosis, and (right) normal leaf.

The first tentative diagnosis of the chlorosis as a mineral deficiency was made by workers of the Georgia Agricultural Experiment Station (1) who stated that it resembled the symptoms of magnesium deficiency in other plants. They initiated experiments with applications of magnesium compounds to the soil in attempts to remedy the disorder. These attempts had not met with success by autumn of 1946 when the writer visited the Georgia Station. The occurrence of the chlorosis in Scuppernong and James at the Coastal Plain Experiment Station, Willard, North Carolina prompted tests of various essential elements as possible remedies.

Experimental Methods

During the summer of 1946 foliage sprays containing copper, manganese, zinc, boron, iron, molybdenum, magnesium, and uramon were applied to replicate vines, both singly and in combinations, on four different dates. Only sprays of magnesium sulfate appeared to influ-

[1]Contribution from the Department of Agronomy, North Carolina Agricultural Experiment Station, and the Division of Fruit and Vegetable Crops and Diseases, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, United States Department of Agriculture. Published with the approval of the Director as paper No. 274 of the Journal Series.

ence the development of chlorosis. They seemed to delay its occurrence but did not prevent it. In June of 1947, therefore, further tests were started to determine the effects of magnesium compounds when applied to the soil and injected into vines.

Soil treatments consisted of magnesium sulfate ($MgSO_4 \cdot 7H_2O$) hoed into the surface over an area of radius 3 feet, at rates of 2.5 and 5.0 pounds per vine. The soil of the vineyard had a surface layer of gray-brown fine sand to a depth of 5 to 7 inches over about 2 inches of yellow fine sand which merged into sandy yellow clay mottled with red, underlain by compact gray clay at about 18 inches. Internal drainage was not ideal for muscadine grapes.

Samples of the soil were taken by compositing five borings under the vine canopy. The surface 6 inches and the second 6 inches were sampled separately. This procedure was carried out under three vines of each variety, so that six samples were thus obtained in each of the James and Scuppernong sections of the vineyard. The samples were analyzed for exchangeable calcium, potassium, magnesium, and exchange capacity, by extraction with neutral normal ammonium acetate. Values for pH were obtained with a glass electrode.

An apparatus similar to that of Southwick (12) was used for injecting magnesium solutions into vines. A solution of $MgSO_4 \cdot 7H_2O$ having a concentration of 100 grams per liter was injected into holes bored in the stalks of four vines of James and three of Scuppernong. The quantities thus injected ranged from 9 to 59 grams of the salt as shown in Table I. These treatments were carried out during a period

TABLE I—THE MAGNESIUM CONTENT OF LEAVES OF JAMES AND SCUPPERNONG, AND THE INCIDENCE OF CHLOROSIS AT HARVEST TIME

Variety and Vine No.	$MgSO_4 \cdot 7H_2O$ Injected (Grams)	Magnesium in Dry Leaves (Per Cent)			Chlorosis Sep 15
		Jun 11	Jun 28	Sep 15	
James					
$R_{21}C_{13}$	9	0.106	0.120	0.106	Extreme
$R_{20}C_{13}$	0	——	——	0.093	Extreme
$R_{20}C_8$	24	0.088	0.187	0.170	Slight
$R_{21}C_8$	0	——	——	0.061	Extreme
$R_{18}C_{22}$	49	0.120	0.205	0.172	None
$R_{19}C_{23}$	0	——	——	0.069	Extreme
$R_{19}C_{13}$	53	0.157	0.294	0.225	None
Scuppernong					
R_3C_{11}	12	——	0.119	0.093	Moderate
R_3C_{13}	0	——	——	0.061	Extreme
R_1C_{22}	43	0.120	0.179	0.205	None
R_4C_{21}	59	0.090	0.162	0.122	None
R_4C_{22}	0	——	——	0.071	Extreme

of low rainfall when plants of the cover crop wilted severely in midmorning. Despite the drought, no vines could be found that would accept solution from the injector (at pressure of 70 pounds per square inch) until about 2:00 p m. Apparently the entry of air into the conducing vessels produced a resistance to moisture movement that was not overcome until the vapor pressure deficit of the leaves increased. When vines finally began to accept solution the time required to inject 500 ml varied with different vines from 15 minutes to 1 hour.

On June 11, the date of injection, samples of leaves were collected

from the treated vines for magnesium determination. In accordance with accepted principles of leaf sampling (13, 14), the most recently matured leaf on a fruit-bearing spur was selected, and 30 such leaves comprised the sample from each vine. Again on June 28 similar samples were collected from the same vines. At this time vines of James receiving the larger quantities of magnesium sulfate exhibited considerable marginal "scorch" in leaves which were young at the time of injection. Leaves that developed later were normal. The samples of June 28 included only normal leaves. No such scorch appeared on Scuppernong vines, which were larger than the James. Leaf samples were again collected on September 15 when fruit was ready for harvest. All samples were analyzed for magnesium at the same time by a method employing thiazol yellow (7) (replacing titan yellow), readings being made on aliquots of a perchloric acid digest with a Coleman Spectrophotometer. The standards for calibration contained calcium in amounts approximating that in the leaf samples to minimize error from this source (10).

Results

Soil treatments with magnesium sulfate produced no appreciable effects. In Table I are recorded the data for magnesium determinations of the dry leaf samples, at three dates of sampling, together with observations on the occurrence of chlorosis at harvest time. The magnesium content of leaves on June 11 ranged from 0.088 to 0.157 per cent. Leaf samples collected June 28, 17 days after injection, showed in every instance a substantial increase in magnesium content with the values varying from 0.162 to 0.294 per cent. Leaves from vines receiving less than 24 grams of magnesium sulfate during the injection showed only slight increase in magnesium. The magnesium contents of leaves collected on September 15 were somewhat lower than those found on June 28, but were still substantially higher than on June 11. Likewise the magnesium contents of leaves from untreated vines were lower on September 15 than were found for treated vines on June 11. Apparently, as the season progresses there is a decrease in leaf magnesuim of all the vines.

The incidence of chlorosis at harvest time was in substantial agreement with the analytical data. Injections of 9 to 12 grams showed little benefit, 24 grams gave moderate improvement, and 43 to 59 grams eliminated the chlorosis completely. No yield data were obtained, since the vines available for these tests were too diverse in size and insufficient in number to furnish statistically valid data. However, all the vines were observed to bear moderate loads of fruit when due consideration was given to the respective sizes of vines.

Analytical data presented in Table II for the soil samples show values for exchangeable magnesium from 0.14 to 0.21 m e per 100 grams in the James section of the vineyard, and from 0.15 to 0.44 m e in the Scuppernong section. Mehlich (8) in a survey of Coastal Plain soils found values for exchangeable magnesium ranging from 0.06 to 2.00 m e per 100 gram. Nelson and Cummings (9) obtained increases in yields of soybeans from supplemental applications of magnesium

TABLE II—EXCHANGEABLE BASES, EXCHANGE CAPACITY, AND pH VALUES OF VINEYARD SOIL SAMPLES

Location	Depth (Inches)	Exchange Bases*			Exchange Capacity*	Exchange Mg / Exchange Capacity	pH
		Ca	Mg	K			
James							
$R_{19}C_3$	0–6	1.34	0.098	0.18	4.96	—	4.65
	6–12	0.68	0.068	0.15	2.64	—	4.33
$R_{20}C_{10}$	0–6	1.04	0.103	0.19	5.28	—	4.66
	6–12	0.83	0.098	0.21	3.10	—	4.46
$R_{20}C_{21}$	0–6	0.78	0.034	0.19	5.16	—	4.60
	6–12	0.35	0.070	0.14	2.32	—	4.53
Mean	0–6	1.02	0.078	0.19	5.13	0.037	4.63
	6–12	0.62	0.079	0.17	2.69	0.064	4.44
Scuppernong							
R_3C_3	0–6	1.99	0.190	—	7.96	—	4.60
	6–12	0.88	0.111	0.31	—	—	4.20
R_1C_{10}	0–6	1.48	0.150	0.15	7.68	—	4.50
	6–12	1.19	0.156	0.23	7.20	—	4.20
R_1C_{21}	0–6	1.31	0.111	0.24	6.76	—	4.48
	6–12	0.63	0.078	0.44	4.40	—	4.40
Mean	0–6	1.59	0.152	0.20	7.47	0.027	4.53
	6–12	0.09	0.115	0.33	5.80	0.057	4.27

*Millequivalents per 100 grams of soil.

sulfate where exchangeable magnesium ranged from 0.15 to 0.20 m e but not where higher levels existed, up to 0.94 m e. Evidently from the values given, the soil of this vineyard may be classed as low in available magnesium.

Prince, Zimmerman, and Bear (11) who made tests of the magnesium supplying power of 20 New Jersey soils suggested that the exchangeable magnesium should be equal to at least 10 per cent of the exchange capacity, in order to furnish adequate magnesium for alfalfa. While this stipulation may not be valid for species other than alfalfa, it is interesting to note that the values for magnesium in the grape vineyard soils amount to 3.7 and 6.4 per cent of the exchange capacity for the surface 6 inches and the second 6 inches, respectively, in the James section. For the Scuppernong section the corresponding figures are 2.7 and 5.6 per cent.

DISCUSSION

The observations presented here are consistent with the view of the Georgia Experiment Station (1) that the late summer chlorosis of muscadine grape varieties is a symptom of magnesium deficiency. The time of its appearance, as fruit formation occurs, and the progressive development from older to successively younger leaves as fruit approaches maturity is reminiscent of magnesium deficiency in citrus, for which the same sequence of events has been described by Fudge (6) and Camp (3). These authors have shown that magnesium is transported from leaves to fruit as the latter develops, so that leaf magnesium declines profoundly as the fruit matures, and deficiency symptoms become prominent in the leaves, if the soil fails to supply sufficient magnesium for both fruit development and maintenance of leaf chlorophyll. The Georgia workers' observation (1) that the

symptom is apparently becoming more severe with successive crops is consistent with the view that soil depletion of an essential element is becoming yearly more pronounced.

The lack of response to applications of magnesium sulfate at the rate of ½ pound per vine per year on a loamy soil in Georgia is not surprising in the light of the experience of Drosdoff (5) who found it necessary to apply 5 pounds per tree for two successive years to remedy magnesium deficiency symptoms in tung on sandy soil. Similar experiences have been reported by a number of other workers. Boynton (2) reviewing the literature on apple nutrition states that "- - - more often than not, little or no benefit has been observed in the first year following treatment. If enough material was applied, partial recovery has usually been observed in the second year after application. But recovery has not always been complete even after 3 years of rather heavy magnesium fertilization".

The evidence available thus far is not extensive enough to justify a positive statement that the chlorosis considered here is a result of magnesium deficiency in the muscadine grape vine, although it is strongly suggestive of this conclusion. Substantiating data are needed from the results of heavy soil fertilization with magnesium compounds, and from sand cultures wherein the symptoms may be reproduced by omitting magnesium from the nutrient solution. Work along both of these lines is in progress.

Summary

Magnesium sulfate in solution was injected into the stalks of vines of James and Scuppernong, in quantities supplying a range of 9 to 59 grams per vine. Vines receiving the larger quantities did not develop late summer chlorosis as did neighboring untreated vines. Leaf samples collected at three dates showed definite increases in magnesium content for injected vines. Soils supporting the vines were low in exchangeable magnesium. Applications of magnesium sulfate to the soil at 2.5 and 5.0 pounds per vine gave no visible results during the first season of treatment.

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Propagation of the Rabbiteye Blueberry

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The difficulty in propagation of the rabbiteye blueberry *(Vaccinium ashei* Reade) has been one factor in limiting the distribution of superior selections. Because of the difficulties encountered, this experiment was planned to obtain further data on rooting media. The experiment was begun in the spring of 1945 at the Georgia Coastal Plain Experiment Station, Tifton, Georgia. This paper is a preliminary report of the first two seasons' work, and the experiment will be continued for several years as the data in the first two seasons are so variable.

Several materials and mixtures have been found satisfactory for rooting the highbush blueberry (*Vaccinium australe* Small). Coville (1) used three-fourths coarse basswood sawdust and one-fourth peat in a ground bed. Johnston (4) obtained good results from the use of German peat in box-type propagating frames. Stene (7) obtained good results from the use of peat in box-type propagating frames, but obtained a higher percentage of rooted cuttings in a mixture of one-half peat and one-half sand than from peat alone in open coldframes. Darrow (2) and Doehlert (3) report a mixture of one-half peat and one-half sand to be satisfactory in ground beds. O'Rourke (6) used one-third finely divided peat to two-thirds clean sand in his propagation. Working with the rabbiteye blueberry, Moury and Camp (5) and Ware (8) report the use of a mixture of one-half peat and one-half sand to be satisfactory.

Materials and Methods

A coldframe 6 feet by 27 feet, which was under a tobacco-cloth shade house, was used for this study. It was located in a sandy loam soil and had 2 inches of coarse cinders in the bottom for drainage. The bed was divided in the center by a partition extending to the top of the bed. Each half was then divided into 10 sections by 6-inch boards extending across the bed and resting on the cinders. Each half of the bed had one section filled to a depth of about 5 inches with the following media: peat; sand: sawdust, one part of peat and one of sand; one part of peat and one of sawdust; one part of sand and one of sawdust; one part of peat, one of sand and one of sawdust; two parts of peat, one of sand and one of sawdust; one part of peat, two of sand and one of sawdust; and one part of peat, one of sand and two of sawdust. The proportions of materials in the mixtures was by volume. Finely ground Florida peat, very coarse sharp sand, and coarse pine sawdust which had been exposed to the weather for about 20 years were the materials used.

Cuttings of the Hagood variety were made from vigorous 1-year-old wood. They were taken about the middle of February and immediately placed in the bed. The cuttings were about 4 inches long and set so that one bud was above the level of the rooting material. They were spaced 1½ by 3 inches apart and 105 were used in each

section. The base of the cutting was against or very near the cinders in the bottom of the bed. Soon after the cuttings were set, the beds were thoroughly soaked and glass sash were placed over one-half of the bed. The beds were watered thereafter at intervals as needed. All sections were given as nearly the same amount of water as possible after being soaked. No fertilizer was applied to the beds.

The cuttings were lifted from the rooting mixture the winter after growth had stopped and after most of the leaves had dropped. Data were recorded on number rooted, length of tops, length of roots, and location of roots formed. Measurements of the longest roots and shoots were made to the nearest ½ inch for each plant. The location of roots was noted as at the base of the cutting, on the side of the cutting or at the base and on the side of the cutting.

Results

The data presented in Table I show that under glass the largest number of cuttings rooted in the mixture of one part of peat, one of sand, and two of sawdust in both 1945 and 1946, the number being 18 and 54 respectively. The second largest number, 16 rooted in the mixture of one part of peat, two of sand, and one of sawdust in 1945 while the second largest number in 1946 was 39 rooted in sawdust. In 1945, 12 cuttings rooted in the mixture of one part of sand and one of sawdust, and in 1946, 38 cuttings rooted in the mixture of one part of peat, two of sand, and one of sawdust. It may be noted that the three materials under glass which produced the largest number of rooted cuttings in both 1945 and 1946 contained at least one-half sawdust.

TABLE I—Number Rooted, Percentage, Average Length of Tops, and Average Length of Roots of Hagood Blueberry Cuttings under Glass in Various Media (105 Cuttings)

Media	Number Rooted		Per Cent Rooted		Average Length of Tops (Inches)		Average Length of Roots (Inches)	
	1945	1946	1945	1946	1945	1946	1945	1946
Glass—peat	4	2	3.8	1.9	8.5	13.0	13.2	15.0
Glass—sand	0	0	0	0	0	0	0	0
Glass—sawdust	8	39	7.6	37.1	3.5	2.6	4.5	7.3
Glass—peat—sand	1	10	0.9	9.5	3.0	12.0	3.0	16.4
Glass—peat—sawdust	2	24	1.9	22.9	2.0	8.8	10.0	10.5
Glass—sand—sawdust	12	13	11.4	12.4	4.1	2.3	6.9	5.7
Glass—1 peat—1 sand—1 sawdust	5	28	4.8	26.7	10.2	6.8	8.0	8.2
Glass—2 peat—1 sand—1 sawdust	8	24	7.6	22.8	2.6	10.9	5.8	7.7
Glass—1 peat—2 sand—1 sawdust	16	38	15.2	36.1	4.7	6.6	6.0	6.8
Glass—1 peat—1 sand—2 sawdust	18	54	17.1	51.4	5.6	3.6	6.5	6.0

Table I also shows that the average length of top growth was greatest under glass in the mixture containing one part of peat, one of sand, and one of sawdust in 1945, but greatest in peat in 1946, being 10.2 inches and 13.0 inches respectively. Top growth was second in 1945 in peat, and in 1946 in the mixture of one part of peat and one of sand, average growth being 8.5 inches and 12.0 inches respectively. In 1945, top growth was third in the mixture of one part of peat, one of sand, and two of sawdust, and in 1946 in the mixture of two parts of peat,

one of sand, and one of sawdust, the average length being 5.6 inches and 10.9 inches respectively. In most cases the greatest top growth is attained in a rooting medium containing considerable peat and containing none or a relatively small amount of sawdust.

The average root growth was greatest in peat in 1945, and in the mixture of one part of peat and one of sand in 1946, being 13.2 and 16.4 inches respectively (Table I). The root growth was second in the mixture of one part of peat and one of sawdust in 1945, and in peat in 1946, the average growth being 10.0 and 15.0 inches respectively. Average root growth was third in the mixture of one part of peat, one of sand, and one of sawdust in 1945, and in the mixture of one part of peat, and one of sawdust in 1946, the average length being 8.0 and 10.5 inches respectively. The root growth under glass was greatest in those media which contained at least one-half peat in all cases except in the mixture containing one-third peat in 1945 which ranked third in average root growth.

The data presented in Table II show the largest number of cuttings rooted in the open bed in the mixture of one part of peat and one of sawdust in 1945, and in the mixture of two parts of peat, one of sand, and one of sawdust in 1946, the number being 59 and 65 respectively. The second largest number rooted in a mixture of one of peat and one of sand in 1945, and in the mixture of one part of peat, one of sand, and one of sawdust in 1946, the number being 45 and 62 respectively. In 1945, the third largest number rooted in the mixture of one part of peat, one of sand, and two of sawdust, and in 1946 the third largest number rooted in a mixture of one part of peat, two of sand, and one of sawdust, the number being 40 and 56 respectively. These data indicate that several mixtures are satisfactory and that further tests will be necessary to determine whether any one medium will be consistently superior as a rooting mixture.

It may also be seen from Table II that the average top growth was greatest in peat in 1945 and 1946, being 9.6 inches and 13.0 inches respectively. Second in top growth was the mixture of one part of peat and one of sand, the average growth being 9.3 inches and 9.8 inches respectively, and the third in both 1945 and 1946 in the mixture of two parts of peat, one of sand, and one of sawdust, the average length being 3.4 and 8.1 inches respectively. The top growth was consistently high in those mixtures which contained at least one-half peat and little or no sawdust.

Table II also shows the average root growth in the open bed was greatest in peat in 1945 and 1946, being 11.6 and 14.2 inches respectively; second in the mixture of one part of peat and one of sand, being 9.5 and 12.0 inches respectively. The average root growth was third in the mixture of two parts of peat, one of sand, and one of sawdust in 1945, and in the mixture of one part of peat and one of sawdust, in 1946, the average being 6.3 and 7.1 respectively. The root growth was generally greatest in the medium which contained at least one-half peat. This was due largely to the greater nutrient content of the peat and to its water-holding capacity.

The roots on all cuttings were formed near the base and grew into

TABLE II—Number Rooted, Percentage, Average Length of Tops, and Average Length of Roots of Hagood Blueberry Cuttings in Open Beds (105 Cuttings)

Media	Number Rooted		Per Cent Rooted		Average Length of Tops (Inches)		Average Length of Roots (Inches)	
	1945	1946	1945	1946	1945	1946	1945	1946
Open—peat	35	15	33.3	14.3	9.6	13.8	11.6	14.2
Open—sand	0	0	0	0	0	0	0	0
Open—sawdust	26	44	24.8	41.9	1.6	1.7	6.3	5.3
Open—peat—sand	45	6	42.9	5.7	9.3	9.8	9.5	12.0
Open—peat—sawdust	59	41	56.2	39.0	2.3	5.1	5.0	7.1
Open—sand—sawdust	3	23	2.9	21.9	1.6	2.0	3.3	4.7
Open—1 peat—1 sand—1 sawdust	27	62	25.7	59.0	2.5	6.1	5.4	6.3
Open—2 peat—1 sand—1 sawdust	28	65	26.7	61.9	3.2	8.1	6.3	6.8
Open—1 peat—2 sand—1 sawdust	36	56	34.3	53.5	2.5	5.7	4.3	5.3
Open—1 peat—1 sand—2 sawdust	40	32	38.1	30.5	2.0	3.3	4.3	4.2

the cinders in the bottom of the bed with the exception of one cutting in the mixture of one part of peat and one of sand. This cutting was dead near the base and has a cluster of roots near the surface of the rooting medium.

The data in Table III show that under the conditions of this experiment a higher percentage of hardwood blueberry cuttings may be expected to root in open beds than in beds under glass. A higher percentage of cuttings rooted in mixtures containing peat than in peat alone in both open beds and those under glass. The greatest average number of cuttings rooted in a mixture of equal parts of peat and of sawdust, however the largest number of cuttings rooted in a mixture of two parts of peat, one of sand, and one of sawdust in 1946 in the open beds. Mixture of peat, sand, and sawdust were satisfactory mixtures.

TABLE III—A Comparison of Open Beds and Glass Covered Beds for Rooting Blueberry Cuttings; Average for Two Years (105 Cuttings)

Media	Cuttings Glass		Rooted Open		Average Length of Tops (Inches)		Average Length of Roots (Inches)	
	No.	Per Cent	No.	Per Cent	Glass	Open	Glass	Open
Peat	3.0	2.8	25.0	23.8	10.7	11.7	12.6	12.9
Sand	0	0	0	0	0	0	0	0
Sawdust	23.5	22.3	35.0	33.3	3.0	1.6	5.9	5.8
Peat—sand	5.5	5.2	25.5	24.3	7.5	9.6	9.7	10.7
Peat—sawdust	13.0	12.4	50.0	47.1	5.4	3.7	10.2	6.0
Sand—sawdust	12.5	11.9	13.0	12.4	3.2	1.8	6.3	4.0
1 Peat—1 sand—1 sawdust	16.5	15.7	44.5	42.4	8.5	3.8	8.1	5.8
2 Peat—1 sand—1 sawdust	16.0	15.2	46.5	44.3	6.7	5.6	6.7	6.5
1 Peat—2 sand—1 sawdust	27.0	25.6	46.0	43.9	5.6	4.1	6.4	4.8
1 Peat—1 sand—2 sawdust	36.0	34.3	36.0	34.3	4.6	2.7	6.2	4.2
Average	15.3		32.1		5.5	4.4	7.2	6.0

It may be noted also from Table III that rooted cuttings in mixtures containing large amounts of peat and small amounts of sand made the greatest root and top growth. No cuttings rooted in pure sand. Root and top growth were smallest in sawdust.

The average root and top growth of cuttings under glass was slight-

ly greater than that of cuttings in open beds. This may be due to shading or competition of cuttings in the open bed for water and nutrients as the number of cuttings was twice as great as under glass. Earlier growth of cuttings under glass may also have been a factor.

Conclusions

Since this paper includes the results of only two years work, definite conclusions cannot be reached. The data indicate that shaded open beds are satisfactory for rooting blueberry cuttings and that mixtures of peat and sawdust or peat, sand, and sawdust are satisfactory rooting materials. In rather extensive propagation work a mixture of equal parts of peat, sand, and sawdust has been satisfactory.

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Some Factors Affecting the Success of Green Wood Grafting of Grapes

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Green wood grafting of grapes is a late spring and early summer method of establishing vinifera *(Vitis vinifera)* grapes on rootstocks. As the name implies, both stock and scion are in a green growing condition when the graft is made. This method of grafting grapes has been used in Europe, in New Zealand as reported by Woodfin (1), and in a limited way in California. The results in California have ranged from complete failure to good success. Green wood grafting tests have been under study for several years at the United States Horticultural Field Station, Fresno, California.

Methods

In these tests the splice or common whip graft without the tongue cut was used. The year preceding the grafting operation the rootstocks were planted in the field or nursery row. The first winter after planting they were pruned to one 2-bud spur per vine. The following spring one of the stronger shoots on each rootstock was allowed to grow. When this stock shoot had made several feet of growth and had attained a diameter of $^3/_{16}$ to $^7/_{16}$ inch (Fig. 1, A) the green wood grafting operation was practiced. Leaves and buds on the rootstock shoot were shaved off (Fig. 1, B) with a sharp knife from the soil level to the desired location of the graft. The graft was usually made about a foot above soil level, thus eliminating the development of any scion roots.

A scion consisting of a green bud with several inches of internode above and below the bud, was taken from a green growing shoot of the desired fruiting variety. The leaf was trimmed from the scion as soon as the scion was taken from the growing shoot. The cut on the scion (Fig. 1, C) was made obliquely across an internode below the bud at an angle of 10 to 20 degrees making the cut surface about 1 to 1½ inches in length. An internode section of 1 to 2 inches long was left above the scion bud. A similar slanting cut was made on the stock shoot in an internode of the disbudded area. The stock and scion were of about the same diameter so that when the cut surfaces of stock and scion were placed together a good fit was obtained. The graft union was wrapped completely (Fig. 1, D) with rubber or other suitable tying material. The scion bud started growth usually 5 to 10 days after the grafting operation. The tie was left in place until the scion shoot had grown a month or more. The rubber tie usually came off of its own accord, but string had to be cut to prevent girdling. Fig. 1, E illustrates a fast-growing graft with the rubber cut 40 days after grafting and indicates the limit in degree of girdling that should take place before cutting the rubber or other tying material. Any stock shoots which grew below the graft union were removed. The shoot growing from the scion bud was tied to a stake to prevent breaking off due to wind or cultural operations.

FIG. 1. The green wood grafting procedure. A, rootstock shoot trained to a stake; B, rootstock shoot disbudded; C, front and side view of the oblique graft cut on stock and scion; D, green wood graft wrapped completely with the rubber tie; E, green wood graft growing with rubber removed indicating limit in degree of girdling that should be allowed.

RESULTS

Tests were made to determine the effects of time of grafting, disbudding of rootstock, selection of scion material, care of scions, length of graft cut, types of tying material, sap passing through the graft union, and soil moisture on success or failure of the green wood grafting operation.

It was found that successful grafts could be made from late April to early August. The grafts made during the earlier and cooler months naturally made more growth with the longer growing period. The difference in growth is indicated by 860 grafts made between June 10th and August 2nd. Grafts made on June 10th averaged 26 inches of growth by September 1st, while those made on August 2nd averaged 7.4 inches. The grafts made in April and early May occasionally produced some fruit the following year.

Disbudding the rootstock shoot was tried at varying periods previous to the actual grafting operation. Disbudding in this report refers to the removal of buds and leaves on the rootstock below the proposed location of the green wood graft. All growth on the rootstock shoot above this future point of grafting was left on until the graft was made. Green wood grafts were made on shoots as follows; no disbudding, disbudded at time of grafting, and at 1, 2, 3, 4, and 7 days previous to grafting. The number of grafts made at these varying intervals ranged from 18 to 22. One hundred per cent stands of green

wood grafts were obtained where the rootstocks were disbudded 4 and 7 days previous to grafting. Disbudding at grafting time, and at 1, 2, and 3 days before grafting produced stands of 80.0, 85.6, 91.0, and 94.6 per cent, respectively. Where no disbudding was practiced on the rootstock shoot, only 5 per cent of the green wood grafts grew. These tests indicate that disbudding of the rootstock shoot should take place at least 4 days previous to the grafting operation. The shorter the time interval between disbudding and grafting, the greater was the amount of sap exuding from the disbudding scars after the shoots were green wood grafted. The loss of sap from these scars apparently accounted for some of the unsuccessful grafts.

Green scions taken from "very tender" to "firm" growing shoots gave successful grafts. Good results were obtained with all of the following types of scion material: (a) tender green growth near the tip of growing shoots, with little or no white pith and only a faint line of white lignified tissue showing near the outer edge of the cut surface; (b) medium tender growth, with partially white pith and a definite line of lignification; (c) green bark, with lignified tissue and pith fully white; and (d) yellowish-green bark, with lignified tissue and fully white pith. The more tender scions required careful handling to prevent crushing during the tying operation but they generally started growth sooner than more mature scions. By careful technic all types of scions gave succeessful grafts; but due to easier handling, scions of type C can be recommended for general use.

Although scions can usually be gathered daily, varieties may be desired for grafting which are located some distance from the place of grafting. Tests were made during 1946 and 1947 with scions cut and held in damp packing material at room temperatures ranging from 65 to 70 degrees Fahrenheit for periods of ½, 1, 3, 5, and 7 days. The scions were collected at the requisite intervals and all used in grafting on the same day. There was no significant difference in successful grafts from the different lots of scions. These tests indicate that scions may be held for at least a week prior to the actual grafting operation if kept in damp packing material at the temperature range indicated. The green scions tended to rot in very damp material, while in dry packing the scions became too dry to make successful grafts.

The type of cut used in making the graft was a smooth oblique slice giving an angle of 10 to 20 degrees between the cut surface and the outer edge of the scion. Various lengths of cut, ½, ¾, 1, 1¼, and 1½ inches, were tested. On June 5, 1947, 132 green wood grafts were made with these five lengths of cut. Only two grafts of the 132 failed to grow, thus indicating that all lengths of cut were satisfactory in obtaining successful grafts. The shorter lengths of cut were more difficult to hold during the tying operation. The average linear growth 3 weeks after grafting for the several lengths of cut from ½ inch up to 1½ inches was 2.7, 2.8, 3.6, 4.4, and 6.0 inches, respectively. Thus longer cuts gave the greater linear growth during the first 3 weeks after grafting. The longer cuts were more easily held in place during the tying operation and are recommended in green wood grafting.

Rubber strands, string, raffia, and florists' tape were used in a test

of tying material. Rubber strands and string were equally satisfactory, producing 95 per cent stands of grafts in comparable tests. Rubber strands were easier to apply and easier to remove, if necessary, than the string ties. Raffia produced stands of 30 per cent, mainly because it tended to loosen and did not hold the graft securely until growth had taken place. Florists' tape gave a 5 per cent stand of grafts. The last two were more difficult to wrap then rubber strands or string. While string was used at first by commercial propagators in the San Joaquin Valley in California, it has been largely replaced by rubber-strand ties. Apparently any tying material that holds the stock and scion tightly for a month or more is satisfactory if it can be efficiently handled. The rubber tie has the advantages of ease of application, of holding the union tightly and of ease of removal if it does not break of its own accord at the proper time.

The relation of sap passing through the graft and exuding from the top of the scion, to the per cent of growing grafts was recorded. Seventy-seven per cent of the grafts grew from which sap exuded from the top of the scions shortly after the grafts were made. Only 40.6 per cent of the grafts grew where no sap exuded. When very tender scion wood was used, sap exuded from only a small percentage of the scions. When the soil was very dry at the time of grafting, sap exuded from only a few scions. Although sap exuding from the scions shortly after grafting is an indication that such grafts are apt to grow, some grafts were found to grow from which no sap exuded.

Commercial grape grafters using the green wood graft consider an abundance of moisture in the soil at grafting time a very important factor in the success of the grafting operation. During the season of 1945, green wood grafts were made in two different plots of vines; one receiving an irrigation every week and the other every third week. Sap exuded from all of the grafts in the weekly irrigated plot and 80 per cent of the grafts grew. In the drier plots, sap exuded from 92.3 per cent of the grafts but only 46.2 per cent grew. Ample soil moisture at the time of grafting in this test was an important aid in the success of the grafting operation.

To further test the application of the green wood graft, green scions of the present season's growth were grafted on 1-year-old wood of rooted cuttings in the nursery rows. In a period of 30 to 40 days after grafting 150 green wood grafts on 1-year-old wood had made an average growth of 7.4 inches per graft, while similar grafts on green stock wood had made 7.5 inches per graft, practically the same growth for the two types of grafts. Green wood scions grafted on 1-year-old wood of rooted cuttings in nursery row produced good grafted vines in one season.

Summary

Green wood grafting is a late spring and early summer method of establishing vinifera grape varieties on rootstocks. The various tests in this report indicate the following procedures: the time of grafting should be as early as stocks and scions are available in suitable sizes. While the grafting can extend over a considerable period, more growth was made by the earlier spring grafts. The stock shoots should

be disbudded at least 4 days previous to the grafting operation. The scions can vary from "tender" to "firm" in stage of growth, but should match the stocks closely as to size. For ease of handling, lignified scions with green bark and white pith were desirable. Scions can be cut as used or kept for short periods up to several days in damp packing material. A length of bevel cut of 1 to 1½ inches on stock and scion gave a better start of growth and was better suited to efficient handling than the shorter cuts. Rubber tying material was more effectively handled, although equally good results in percentage of successful grafts were obtained with string ties. Raffia and florists' tape were unsatisfactory. Sap exuding from the top end of the scions shortly after grafting was an indication of a better stand of grafts than if no sap exuded. Some grafts, however, grew from which no sap exuded. Abundant soil moisture was an aid to succesful grafting. Green wood scions were successfully grafted on 1-year-old wood of rooted cuttings growing in nursery rows. The green wood graft supplements other methods and may develop into a major grape grafting practice.

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Further Observations on the Control of Mummy Berry on Cultivated Blueberries[1]

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Loss of fruit from the effects of the mummy berry disease, caused by the fungus *Monilinia vaccinii-corymbosi* (Reade) Honey (2), has been rather heavy in several cultivated blueberry plantings in Massachusetts during the past few years. Consequently, experiments were started in the spring of 1945 to develop a satisfactory method of control. As a result of the first experiments Bailey and Sproston (1) found that four Fermate sprays gave enough control to warrant further trial. The results presented herein are a report on the continuation of that work.

An experiment was set up in 1946 to test the suggestions (1) that more sprays and better timing of them in relation to rainy periods might result in better control. Five plots were laid out — one received nine sprays; one, eight omitting the first; one, seven omitting the first two; one, six omitting the first three; and one was left unsprayed. Fermate at the rate of 1½ pounds per 100 gallons was used on all sprayed plots. Sprays were applied March 29, April 18 and 27, May 6, 13, 20 and 29, and June 7 and 20. No sticker was used until the last spray when fish oil was added. A special effort was made to get sprays on ahead of rainy periods. When spraying had to be done during a rain, the Fermate was increased to 2 pounds per 100 gallons. The first apothecium was found on April 18 and the last on May 29. The first blossoms opened on Cabot on May 2 and the last were on Jersey on June 13. Fig. 1 shows graphically the dates and amounts of rainfall, the dates sprays were applied, the dates the first and the last apothecia were found, and the dates the first flower opened and the last bloom was found.

The severity of infection was obtained by stripping off samples of 200 to 300 berries from each of three bushes per variety per plot and counting the infected and uninfected berries. The results are presented in Table I as the percentage of infected berries.

Discussion of 1946 Results

In early March there was a period of unusually warm weather. From March 25 through March 30 the temperature never went below freezing. The maximum temperatures on March 26, 27, 28 and 29 were 71, 67, 79 and 83 degrees respectively. Since bud development was rapid during this period, it was thought that apothecia would soon appear. This accounts for the earliness of the first spray.

The data were compared by analysis of variance after transforming the percentages to degrees of angles. The differences both between

[1]Contribution No. 657 of the Massachusetts Agricultural Experiment Station. During the 1947 season Dr. O. C. Boyd, Extension Pathologist, gave valuable assistance in planning and carrying out the experiment and Dr. W. D. Weeks, Research Assistant in Pomology, helped collect the data. To these men the author expresses his thanks.

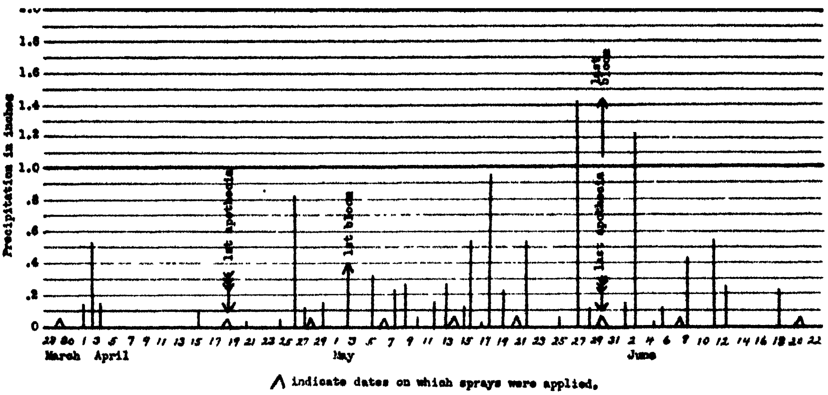

FIG. 1. Distribution of rain during the spraying period (1946).

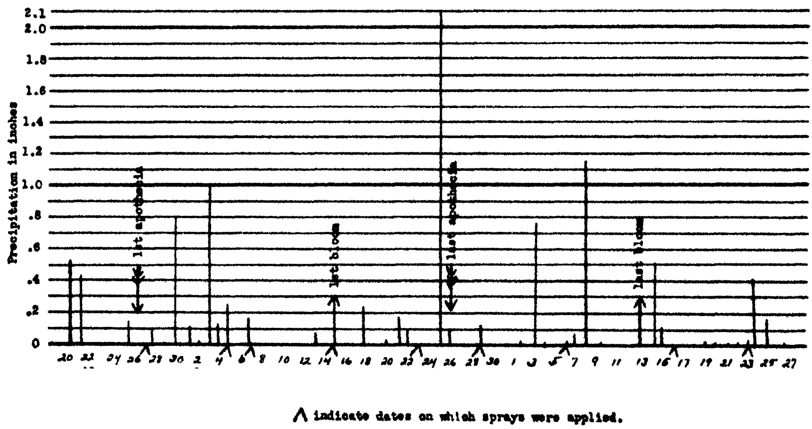

FIG. 2. Distribution of rain during the spraying period (1947).

varieties and between treatments were found to be significant. The treatment means, both as percentages and as angles in degrees, are given in Table I. The differences between the unsprayed and each of the sprayed plots are all significant. Spraying reduced the number of mummied berries by about one-half as in 1945. The only significant difference between sprayed plots is that between eight and nine applications. It appears, therefore, that increasing the number of sprays has given little better results than were obtained from four sprays in 1945 (1). Since omitting the first three sprays results in as good control as where they were applied, and since these three sprays were all applied before the first blossoms opened on May 2, it would appear that infection takes place through the open blossoms. The data presented in 1945 (1) add support to this assumption. The last spray was

TABLE I—Mummy Berry. Percentage of Infected Fruits in Sprayed and Unsprayed Plots in 1946

Variety	Number of Sprays				Unsprayed
	9	8	7	6	
Rancocas	2.3	2.4	3.4	—	10.[illegible]
Cabot	1.5	4.0	2.4	2.7	4.5
Concord	2.1	8.8	3.5	—	10.7
Stanley	4.5	8.0	3.1	—	11.1
Pioneer	5.7	5.8	7.0	3.6	8.0
Wareham	3.5	9.5	6.6	7.1	6.4
Jersey	4.4	4.3	5.8	8.7	8.0
Scammell	3.7	6.3	5.0	—	9.1
Pemberton	4.2	5.5	5.7	—	6.8
Rubel	3.9	4.9	4.5	4.3	6.6
Treatment means:					
In per cent	2.5	5.8	4.6	5.0	8.0
In degrees	10.73	13.88	12.36	13.00	16.44

Difference in degrees necessary for significance = 2.52.

applied on June 4 after most of the blossoms were off. When this spray was applied alone, it gave little or no control. Where three earlier sprays were applied, considerable control was obtained.

Experiments in 1947

Since increasing the number of sprays had resulted in little improvement in control, it was decided to try increasing the amount of Fermate, the use of a different spray material, and the addition of a sticker to the sprays.

A series of six plots was laid out, one of which received Fermate at the rate of 2 pounds per 100 gallons; a second, Fermate 2 pounds plus Goodrite p.e.p.s. 1 quart (containing 1 pound of active ingredient); a third, Bordeaux mixture 4–4–50; a fourth, Bordeaux plus 1 quart of p.e.p.s.; a fifth, 2 quarts of p.e.p.s.; and the sixth was left unsprayed. Goodrite p.e.p.s. was chosen as the sticker because it is a new material which seemed to merit trial and was reported to have some fungicidal value in addition to its adhesive properties.

Sprays were applied on April 27, May 5 (finished May 7), 15, 23, 29, June 6, 16 and 23. The first apothecium appeared April 26 and the last May 26. The first blossoms appeared on Cabot on May 15 and the last were on Jersey on June 13. The first mummies were found on Rancocas on June 27. As in 1946 there were very few cases of blossom and twig blight types of infection.

In order to obtain accurate information as to when the mummies appear, the method of collecting data was changed. As soon as mummies began to appear two bushes on each of three varieties per plot were gone over carefully and each cluster on which there were mummies was tagged. The mummied berries were counted, picked and discarded so that they would not be recounted. Tagging was done on July 11, 14, 18, 20, 26 and 30. The three varieties Cabot, Concord and Jersey, were used because they are early-, mid-season- and late-blooming varieties respectively. In Table II the results are given as the total number of mummies per variety which appeared on all plots on each of the six dates.

TABLE II—MUMMY BERRY. TOTAL NUMBER OF MUMMIES WHICH APPEARED ON ALL PLOTS ON EACH DATE (1947)

Variety	Dates					
	Jul 11	Jul 14	Jul 18	Jul 20	Jul 26	Jul 30
Cabot	99	118	270	—	156	—
Concord	136	171	—	354	336	—
Jersey	161*	—	—	779	848	106

*Only the two unsprayed bushes were tagged.

Table III shows by varieties and treatments the numbers of fruit clusters on which mummies appeared, the numbers of mummies, the percentages of fruit clusters on which mummies appeared and the treatment means both as percentages and as angles in degrees.

DISCUSSION OF 1947 RESULTS

The data in Table II show that mummies appeared over a period of about a month, from early to late July. The peak of mummy appearance occurred slightly earlier on the early-blooming variety Cabot than on the mid-season blooming variety Concord. The peak of appearance for Jersey, a very late-blooming variety, occurred considerably later than that for either Cabot or Concord. The count of mummies for Jersey on July 11 is not comparable with that for Cabot or Concord because counts were made on only the two unsprayed bushes. It is much easier to spot berries which will become mummies on Jersey than on Cabot or Concord. The infected berries become very hard and the skin turns a yellowish green before any other signs of mummification appeared. Therefore, counts made on Jersey on July 11 would not be strictly comparable to those on other varieties. Further counts on Jersey were postponed until the external symptoms were similar to those on other varieties.

TABLE III—NUMBER OF INFECTED CLUSTERS, NUMBER OF MUMMIES, TOTAL NUMBER OF FRUIT CLUSTERS, AND PERCENTAGE OF CLUSTERS INFECTED, PER PLOT ON EACH OF THREE VARIETIES ON SPRAYED AND UNSPRAYED PLOTS OF CULTIVATED BLUEBERRIES (1947)

	Cabot				Concord				Jersey				Treatment Means	
	No. Infected Clusters	No. Mummies	Total No. Clusters	Per Cent Infected Clusters	No. Infected Clusters	No. Mummies	Total No. Clusters	Per Cent Infected Clusters	No. Infected Clusters	No. Mummies	Total No. Clusters	Per Cent Infected Clusters	Per Cent	Angles in Degrees
Unsprayed	209	354	1,020	20.5	136	169	396	34.3	224	379	439	51.0	34.7	36.11
Fermate	56	65	401	14 0	122	135	1,775	6.9	266	395	730	36.4	17.6	24.77
Fermate+p.e.p.s.	17	19	418	4 1	—	—	—	—	77	98	491	15.7	9.1	17.51
Bordeaux	82	91	586	14 0	344	413	1,103	31.2	286	479	531	53 9	31.9	34.39
Bordeaux+p.e.p.s.	17	98	581	13.3	—	—	—	—	187	282	464	40.3	25.6	30.40
p.e.p.s.	52	54	555	9.4	236	294	979	24.1	207	320	517	40.0	23.3	28.38

Difference in degrees necessary for significance = 5.64.

The results of the spray tests in Table III show that Fermate alone

was significantly better than the unsprayed as in former years. Fermate plus sticker was significantly better than unsprayed or Fermate alone. The sticker, p.e.p.s., was significantly better than unsprayed and not significantly less effective than Fermate alone. It was significantly less effective than the Fermate plus p.e.p.s combination. Bordeaux was not significantly better than unsprayed but Bordeaux plus p.e.p.s. was.

These results suggest that the effectiveness of Fermate can be considerably increased by the addition of Goodrite p.e.p.s. Certainly this is the most effective combination tried so far. Since the p.e.p.s. alone seemed to give considerable control, it is probable that it adds to the effectiveness of the Fermate by both its adhesive and its fungicidal properties.

Bordeaux alone appeared quite ineffective. When p.e.p.s. was added, the control was improved enough to be significantly better than the unsprayed. Because of the effectiveness of p.e.p.s. alone, it seems probable that the effectiveness of the Bordeaux-p.e.p.s. combination resulted more from the p.e.p.s. than from the Bordeaux.

Summary

1. In three different years spraying with Fermate alone has cut loss from mummy berry about in half.

2. The addition of the sticker p.e.p.s. increased the effectiveness of the Fermate spray.

3. Bordeaux was ineffective in controlling mummy berry.

4. Goodrite-p.e.p.s. appeared to have fungicidal value.

5. The data suggest that infection takes place during the blossoming period.

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A Sweetpotato From Tinian Island Highly Resistant to Fusarium Wilt

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THE Bureau of Plant Industry, Soils, and Agricultural Engineering of the United States Department of Agriculture and several cooperating State Experiment Stations are conducting a comprehensive breeding and improvement program with sweetpotatoes. In this work use is made of available sweetpotato and related species of both domestic and foreign origins. Numerous selections or varieties from foreign sources have been and are being introduced and tested for their properties and potential value either as new varieties or as parental materials used in breeding. One of the objectives of this program is the development of varieties with appreciable resistance to the fusarium wilt, or stem rot disease, caused by *Fusarium batatatis* Wr. and *F. hyperoxysporum* Wr. None of the currently important culinary types of sweetpotatoes possess any appreciable degree of resistance to this disease, and until recently, none of the important starchy or industrial type sweetpotatoes possessed more than a moderate resistance to the trouble.[1]

In the fall of 1946 three sweetpotato selections collected on Tinian Island in the Marianas by Lt. Sydney P. DuBose, of the U. S. Army Air Forces, were released to the Division of Fruit and Vegetable Crops and Diseases by the Division of Plant Exploration and Introduction of the Bureau of Plant Industry, Soils, and Agricultural Engineering. Of these three, one designated P. I. 153655 has been found to possess a higher degree of resistance to stem rot, even under very severe greenhouse testing conditions, than any selection or variety tested to date. Because of this unusual degree of fusarium resistance as well as a promising yielding capacity, it is believed that this selection will be valuable as a breeding parent or possibly even as a commercial feed or industrial variety. Small quantities of propagating stock have been made available to sweetpotato breeders at several experiment stations. Others may wish to make use of this selection.

PLANT DESCRIPTION

Vines of P. I. 153655 are slender, moderately long, and of trailing habit. Internodes are short. Trailing stem is green, sometimes with a purple overcast, and there is purple pigmentation around the axillary buds. Foliage density is heavy. Leaf blades are only medium to small in size and are deeply and rather finely cut. Petioles are short and slender. Leaf color is dark green often with bronzing on terminal growth, and leaf veins are purple. Roots have rose-purple skin and

[1]Since the inception of the present improvement program Pelican Processor, an industrial-type seedling selection, has been released by the Louisiana Experiment Station, and another seedling selection, B-196, also an industrial type, is scheduled for early release by the Bureau of Plant Industry, Soils and Agricultural Engineering and cooperating State stations. Both of these selections are resistant to stem rot under commercial growing conditions.

almost pure white flesh color. They are medium to large in size and globular to ovoid or heavy tapered in shape.

Wilt Resistance and Yield Trials

Following receipt of the first plants from the quarantine station at Glenn Dale, Maryland, the selection was propagated by vine cuttings and was subsequently tested for wilt resistance in replicated greenhouse trials in the winters of both 1946–1947 and 1947–1948. It was also included in a replicated field performance trial in the summer of 1947.

The wilt testing technique used was adapted from that of Wellman (1) devised for wilt testing of tomatoes. In the present tests vine cuttings, usually in lots of 25 for each replicate in each test, rooted in sand for 10 days to 2 weeks, had their basal ends cut off with a sharp knife and their roots pruned back to about 1½ to 2 inches in length immediately before dipping into a composite macerated ("blended") spore-mycelial suspension prepared from 5-day liquid nutrient cultures of three to five virulent wilt strains. The cutting plants were then set at once in a soil bench in a greenhouse that was maintained at 70 to 85 degrees F. Counts of plants killed were made at 2, 3, and 4 weeks and at the 4-week period remaining plants were dug and the stems split to ascertain the extent of wilt injury. Plants were classified into grades according to the extent of vascular injury. The numbers of plants in the several grades were multiplied by arbitrarily assigned numerical values for these grades, and from the products over-all total susceptibility scores were determined for each cutting lot. In order to facilitate interpretation, all scores were adjusted to a 25-plant basis. Numerical values assigned for the grades of wilt injury were as follows: dead, 4; severe, 3; moderate, 2; slight, 1; and none, 0. With these values and with 25-plant lots, the maximum score possible was 100 where all 25 plants were killed and 0 if there had been no wilt infection symptoms evident.

Wilt susceptibility scores obtained in four greenhouse tests in 1947 and 1948 of P. I. 153655 in comparison with Pelican Processor (L–5) and B–196,[2] that are resistant; Triumph, a tolerant or partially resistant variety; and Unit I Porto Rico and Nancy Hall, both highly susceptible commercial varieties, are shown in Table I. The highest susceptibility score obtained with P. I. 153655 in any test was 29.4, a rating far lower than the lowest score (49.3) obtained with either of the resistant selections Pelican Processor and B–196. In very few cases were any plants of P. I. 153655 more than moderately injured and many showed no evidence whatever of wilt invasion, whereas the field resistant Pelican Processor and B–196 always had several plants killed and severely injured and rarely had any plants apparently free of injury. It must be emphasized that these greenhouse test conditions were far more severe than are likely ever to be encountered under field conditions and that severe injury to such resistant selections as Pelican Processor and B–196 is likely to be infrequent under ordinary

[2]One test only.

TABLE I—WILT SUSCEPTIBILITY OF SOME SWEETPOTATO SELECTIONS AND VARIETIES INCLUDED IN FOUR GREENHOUSE TESTS AT BELTSVILLE, MARYLAND, IN 1947 AND 1948*

Selection or Variety	Total No. Plants Tested	Average Susceptibility Scores**					Relative Wilt Resistance
		Test 1 (Feb. 1947)	Test 2 (Mar. 1947)	Test 3 (Jan. 1948)	Test 4 (Mar. 1948)	Mean For Four Tests	
P. I. 153655	254	12.5	18.5	16.9	29.4	19.3	Highly resistant
Pelican Processor	160	69.0	49.3	65.0	88.0	67.8	Resistant
Triumph	215	76.0	81.1	95.5	98.0	87.7	Tolerant
Unit I Porto Rico	220	98.6	99.0	100.0	100.0	99.4	Very susceptible
Nancy Hall	92	94.0	100.0	100.0	100.0	98.5	Very susceptible
B-196	31	—	—	57.3	—	57.3†	Resistant

*Wilt strains 7287c, 7313a, 7339b, 7356c, 7363c, S. C.-45-3b, and S. C.-45-4b used in these tests.
**Sum of products of number of plants in the several susceptibility classes × the corresponding arbitrary class values (dead = 4; severe = 3, moderate = 2; slight = 1, none = 0) adjusted to a 25-plant-sample basis. Lowest numerical scores indicate greatest wilt resistance.
†One test only.

field growing conditions. In these greenhouse tests killing of plants of both Unit I Porto Rico and Nancy Hall approached 100 per cent. Under field conditions rarely more than 20 to 30 per cent of the plants of either of these varieties are killed by stem rot.

The yielding capacity, solids content, and starch content of P. I. 153655 and of Pelican Processor, B–196, and Triumph, as determined from a replicated field test at Beltsville, Maryland, in 1947, are shown in Table II. Data for Unit I Porto Rico, grown in an adjacent replicated test, are included for comparative purposes. The yield of P. I. 153655 in this test was as high as or slightly higher than that of Pelican Processor and was significantly higher than that of Triumph, but it was significantly lower than that of B–196. (Other studies have shown B–196 to outyield Pelican Processor in more northerly growing areas but to be outyielded by Pelican Processor in some locations in the deep South). Both the solids content and the starch content of P. I. 153655 selection were somewhat lower than the corresponding values for the other varieties shown, with the exception of Unit I Porto Rico.

TABLE II—YIELD, SOLIDS CONTENT, AND STARCH CONTENT OF SELECTION P. I. 153655 IN A COMPARATIVE TEST AT BELTSVILLE, MARYLAND, (1947)*

Selection	Average Yield Per Acre (Bu)	Rank in Yield*	Solids Content (Per Cent)	Starch Content (Per Cent)
P. I. 153655	275	3	29.65	21.6
Pelican Processor	255	8	33.10	25.1
B-196	402	1	31.75	24.1
Triumph	159	18	32.65	24.2
LSD (5 per cent level)	89			
Unit I Porto Rico†	176	—	29.30	18.8

*Twenty-five selections in complete test; plantings in triplicate.
†Data from a test adjacent to that in which the other varieties were compared.

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Baking Sweet Potato Tests in Hawaii[1]

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For many centuries the sweet potato has been a staple food in the Pacific Islands. How and when it got to some of them from Mexico, its most probable origin center, is lost even in legend. In most of Polynesia great antiquity is likely since the Hawaiians apparently brought it with them on their original migration about 500 A. D. The Maori name, kumara, and the Tahitian, kumar (1) are practically identical with the Peruvian-Chilean native name kumar (2).

Native cultivation in Hawaii was exclusively by vegetative propagation, consequently most if not all of the many Hawaiian named sorts of this hexaploid species (3) arose as somatic mutations. Most clones cultivated in Hawaii will flower and set some degree of seed between October and May. The probability is therefore high that some native clones arose from chance seedlings.

Local preference ran toward root types with relatively few roots but of large size, 6 to 8 pounds in some roots 6 or 7 months after setting. Quality in baking and storage values comparable to that of standard mainland sorts is relatively low. On the other hand these latter in Hawaii are not well adapted in tolerance to prevailing diseases and insects.

The objective of the present study was to evaluate some of the better Hawaiian sorts as bakers compared with some newer seedlings produced by mainland and local breeders.

Materials and Methods

Among local sorts included in this study are several seedlings and older clones, *viz.* Waialua (sometimes erroneously called Yellow Yam), Tantalus, 35.9, 35.23 (both derived by open pollination — parentage records lost), and four new seedlings, H S P A 1, 2, 3 and 4 obtained by A. J. Mangelsdorf of the Hawaiian Sugar Planters' Association from open pollination of Huamoa, Nancy Hall, Pratt-Kaneohe, and Tantalus respectively. Mainland sorts included the standard varieties, Nancy Hall, Queen Mary and a new United States Department of Agriculture seedling B–4282, derived from a cross between true Yellow Yam and Nancy Hall.

The test was designed to carry a main plot of 11 sorts in three completely randomized blocks. Each sort in each block contained 15 hills spaced 2 feet between hills and 4 feet between rows. This main plot was repeated three times at 30-day intervals beginning the 3rd week in February, and ending the 3rd week of April. Planting was from terminal stem cuttings set during the initial irrigation. Fertilizer was 4–12–8 for plot 1, and 12–30–6 for plots 2 and 3. It was applied as a side dressing about 3 weeks after setting, and at a rate of 1500 pounds per acre.

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[1]Published by permission of the Director of the Hawaii Agricultural Experiment Station as technical paper No. 168.

At harvest, 5 months after setting, only the middle 10 hills per row were dug by hand with a 4-pronged spading fork. Thus the sampling unit was a single row of 80 square feet, and at the test's ending each sort was represented by nine replications totalling 720 square feet.

The total of roots for each 10 hill sample was bulked and classified as to weight of (a) marketable bakers, (b) culls, and (c) jumbos, that is roots exceeding 1.3 pounds. Before taking further data the roots were cured for 8 to 10 days on wire trays in a quonset hut. Next they were classified by sorts for resistance to insect and disease injury. Finally a 10-pound sample for each sort was baked, and a jury of 13 judges from the University Extension Service classified the sorts for quality in: color, texture, flavor and fiber. Grading in each character was based on a 4-point scale with highest score for best grades.

Final estimation of desirability for table stock was determined from a product index obtained by multiplying the scores given each sort for the four characters: weight in pounds per acre, per cent marketable roots, per cent disease and insect free roots, and baking index. The latter was itself a product score obtained by multiplying the scores for color, texture, flavor, and fiber.

The baking test was given only to the section planted in February, but all other features of yield were based on total data of all three sections of the experiment. The variety Porto Rico was not available for the first two plots and appeared only in that planted in April.

Harvest Data

A variance analysis of the weight of marketable roots in the factors of this experiment is given in outline in Table I. The experimental

TABLE I—Variance Analysis of Weight of Marketable Roots (Data on Eleven Sweet Potato Sorts Planted in Three Sections at 30-Day Intervals Beginning February 19, 1947)

Sources of Variation	Degrees of Freedom	Mean Squares	F Ratios		
			Observed	Tabular	
				5 Per Cent	1 Per Cent
Varieties	10	1,140.34	29.32**	1.98	2.61
Plots	2	188.97	4.86*	3.14	4.95
V × P	20	75.77	1.95*	1.73	2.18
Replicates	2	15.52	0.33	—	—
Error	64	38.80	—	—	—

*Significant at 5 per cent probability.
**Significant at 1 per cent probability.

error for reference was calculated as the 64 degrees of freedom for the replicate interactions. On this basis the mean square for varieties was highly significant and those for plots and interaction between varieties by plots were significant. Because time of planting the three plots was confounded with a fertilizer difference, data are not clear as to which of the three conditions produced the significantly heavier yields in plots 2 and 3: (a) better growing conditions in the March and April plantings, (b) the superior nutrient value of 12–30–6 compared to 4–12–8 fertilizer, or (c) both. Climatic conditions in Febru-

ary would hardly be unfavorable enough (compared with March and April) to account for a significantly lower yield, hence the superiority of 12–30–6 over 4–12–8 is probably solely responsible for the difference.

Variety differences between the 11 sorts are the most important information in the analysis. These have been further studied in Table II with the aid of a selection index, as previously described, embrac-

TABLE II—PERFORMANCE RECORDS OF EIGHT HAWAIIAN SWEET POTATO SORTS COMPARED WITH THREE MAINLAND SORTS IN ONE EXPERIMENT, AND RECORDS FROM PORTO RICO FOR GENERAL COMPARISON

Variety	Yield Lbs Per Acre (720 Sq Ft)	Per Cent Grade A	Per Cent Disease and Insect Free	Baking Value	Selection Index
Waialua	12,568.0	67	71	24	144
Tantalus	8,578 9	50	36	3	5
35.23	11,511.5	51	59	19	66
35.9	8,109.6	66	75	3	13
H S P A 1	19,913.6	49	55	10	54
H S P A 2	28,122.8	62	61	8	85
H S P A 3	33,460.4	62	67	27	375
H S P A 4	17,971.3	64	91	9	96
Nancy Hall	22,063.4	77	42	11	80
Queen Mary	13,706.9	69	44	14	58
B-4282	28,362.0	74	62	30	390
Least significant difference					128
Porto Rico	29,856.8	58	38	33	218

ing information from all measurable sources. The least significant difference between indexes, 128, shows that HSPA 3 and B–4282 have indices which are significantly superior to the remaining nine sorts. Both yield well in total yield, yield of marketable bakers, and baking value. Although neither one is outstanding in disease and insect tolerance, both are superior in these regards to all standard varieties.

Two remarkable features about B–4282 are its semi-bush habit, and the attractiveness of its leaves to rose beetle feeding. The combination makes most observers prematurely disappointed until they harvest the roots. Despite the short stem, however, B–4282 has ample leaf area. By actual count of 100 stems the number of leaves per inch in five of the varieties of this test is as follows:

Variety	Length of Stems (Inches)	Number Leaves Per Stem	Number Leaves Per Inch
Porto Rico	22.05	20.58	.96
Waialua	29.07	16.97	.60
Nancy Hall	24.39	23.22	.98
B–4282	10.53	21.98	2.09
HSPA 3	22.28	17.71	.82
Highly significant difference			.23

The poor showing of Nancy Hall is due chiefly to its disease and insect susceptibility. Much of the poor showing in baking quality is doubtless due to the method of scoring more highly colored flesh highest. At the same time, however, the great majority of the judges graded it low in texture and fiber and only mediocre in flavor. Five of

the 13 judges, who were previously acquainted with the variety characters, especially its light flesh color, expressed preference for it.

Porto Rico was unfortunately included only in the third section of this experiment. The baking data were taken from an entirely different experiment harvested a month later. Consequently comparison of this standard variety with any of the 11 can only be done with considerable reservations. From the performances recorded at this time, however, together with information from the many other tests held at this Station, Porto Rico always scores highest on baking quality and in the upper group on yield. Its chief drawback is susceptibility to disease and insects.

Summary

In a test of 11 sorts of mainland and local varieties and newly produced seedlings, significant differences in yield were probably due to differences in fertilizer. The two sections which received 12–30–6 yielded higher than that which received 4–12–8.

Highly significant differences in yield were traced to genetic variation between the 11 sorts.

When all characters measured were included in a general index of quality the two seedlings, B-4282, and HSPA 3, were outstanding in superiority to the remaining nine sorts.

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Preliminary Studies on the Top System of the Bunch Porto Rico Sweet Potato

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AT the present time, many farmers in south Georgia are growing a strain of the Porto Rico variety of sweet potato known locally as Bunch Porto Rico. This strain has short stout stems, very short internodes and comparatively large, dark green leaf blades. Since preliminary yield tests and reports from local growers indicate that this strain produces yields comparable with other strains, studies were made to determine the comparative leaf area of the Bunch type. Pertinent results obtained in 1946 and 1947 follow.

MATERIALS AND METHODS

Roots of the Bunch strain and a NonBunch (vining) strain were bedded in an electric heated hotbed and sprouts were set in adjacent rows of a Tifton sandy loam on May 28, 1946 and April 27, 1947. To obtain data on the number and length of stems, number of leaves on each stem and the area of leaves, five plants of each strain were selected at the end of 60 days and 90 days in 1946, and six plants were selected at the end of 60, 90 and 120 days in 1947. Leaf area was obtained by tracing, with the aid of an illuminated box, an outline of each leaf on wrapping paper, weighing the paper cutouts, and calculating the area with a proportionality factor based on the weight of a given area of paper.

DISCUSSION

The data, presented in Tables I and II, show that the Bunch Porto Rico had much shorter stems, a greater number of leaves per unit

TABLE I—MEAN LENGTH OF STEMS OF BUNCH AND NON-BUNCH STRAINS OF PORTO RICO (1946–1947)

Strain of Porto Rico	Mean Length Stems Per Plant (Inches)					Maximum Length Stems Per Plant (Inches)				
	1946		1947			1946		1947		
	60 Days	90 Days	60 Days	90 Days	120 Days	60 Days	90 Days	60 Days	90 Days	120 Days
Bunch	10.5	12.9	7.4	10.3	16.4	17.0	19.5	18.0	22.0	32.0
Non-Bunch	30.5	45.0	25.7	35.9	43.8	47.5	91.2	62.0	92.0	124.0

TABLE II—MEAN NUMBER OF LEAVES PER UNIT LENGTH OF STEM AND MEAN LEAF AREA OF BUNCH AND NON-BUNCH STRAINS OF PORTO RICO (1946 AND 1947)

Strain of Porto Rico	Mean Number Leaves Per Inch Stem			Mean Area Leaves (Sq Cm)				
	1947			1946		1947		
	60 Days	90 Days	120 Days	60 Days	90 Days	60 Days	90 Days	120 Days
Bunch	1.67	1.13	0.55	108.8	101.1	108.6	102.5	88.6
Non-Bunch	0.56	0.42	0.23	60.4	73.4	85.3	76.8	78.8

length of stem and a somewhat greater leaf area than the nonbunch or vining strain. In other words, the stem system of the Bunch Porto Rico is strikingly short and compact in comparison to that of nonbunch strains. Although certain growers in south Georgia believe the Bunch Porto Rico produces marketable yields equal to that of normal types, definite information on this point is lacking. Experiments are in progress at the Coastal Plain Experiment Station to obtain this needed information.

Summary and Conclusion

1. At the Coastal Plain Experiment Station, Tifton, Georgia, preliminary studies were made to obtain quantitative information on the stem system of the Bunch Porto Rico. Data were obtained on length of stems, number of leaves per unit length of stem and leaf area.
2. The Bunch Porto Rico has a much shorter and compact stem system in comparison to that of nonbunch strains.

Effects of Rates of Nitrogen on the Relative Yields of Sweetpotato Vines and Roots

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THE Alabama Agricultural Experiment Station (Auburn) in 1942 began studies with intensive methods of producing sweetpotatoes. The phase of study reported here relates to the effect of nitrogen rates on vine and root yields, and had two primary objectives: first, to determine the effects of nitrogen on the yield of vines and roots; second, to determine the relation between sweetpotato vine and root production including all grades.

Where sweetpotatoes are used in a livestock program, the yield of vines is important, since the vines furnish part of the feed as well as the roots. A heavy vine growth has been thought to reduce the yield of roots.

The studies were made in concrete bins. The soils used were sandy loams of the Chesterfield, Norfolk and Hartsells soils, and a clay loam of the Decatur soil. The Chesterfield soil, essentially a Norfolk surface soil on a Cecil subsoil, occurs where the Coastal Plain and Piedmont soils join. Norfolk is one of the most widely distributed soils of the Coastal Plain region. The Hartsells is one of the most widely distributed soils of the Lower Appalachian Plateau region. The Decatur is one of the most widely distributed soils of the Limestone Valley region. With the exception of Chesterfield, all of the soils used were imported. The soils were composited in the bins, methods for which were reported in a previous paper (1). The Norfolk soils used in separate tiers of bins came from different sources.

Bins were $^1/_{820}$ of an acre in size for the Chesterfield soil and $^1/_{640}$ of an acre for the other three. The treatments were replicated four times on the Chesterfield soil and two times on Norfolk, Decatur, and Hartsells soils. The Porto Rico variety of sweetpotato was used in the experiment.

Sweetpotatoes were grown for 2 years on Chesterfield soil and for 3 years on Norfolk, Decatur, and Hartsells soils. The rates of nitrogen ranged from 0 to 80 pounds per acre on Chesterfield and Norfolk soils, and from 0 to 120 pounds per acre on Decatur and Hartsells soils. With each rate of nitrogen, adequate amounts of phosphorus and potash were applied to all plots.

RESULTS

In Table I are given the yields of both vines and roots from the different rates of nitrogen. Within the range of treatments used in the experiments, there was very little evidence to indicate that conditions favoring vigorous vine growth resulted in smaller yields of roots. Except where pointed out, vine yields and root yields were significantly increased for each increase in nitrogen application.

On the Chesterfield soil there was a significant increase in yield of both roots and vines for each increment of nitrogen from 0 to 80

TABLE I—YIELDS OF SWEETPOTATOES AND VINES ON DIFFERENT SOILS WITH DIFFERENT RATES OF NITROGEN

Nitrogen Applied Per Acre* (Lbs)	Yields Per Acre 2-Year Average Chesterfield Soil Roots (Bu)	Vines (Lbs)	Yields Per Acre 3-Year Average Norfolk Soil Roots (Bu)	Vines (Lbs)	Nitrogen Applied Per Acre* (Lbs)	Yields Per Acre 3-Year Average Decatur Soil Roots (Bu)	Vines (Lbs)	Hartsells Soil Roots (Bu)	Vines (Lbs)
0	188	2,450	207	4,549	0	295	7,339	316	5,308
20	**	**	355	7,170	30	370	10,914	465	8,448
40	364	5,808	422	9,876	60	401	13,139	532	11,059
60	420	8,176	463	13,039	90	405	15,569	558	13,453
80	457	9,525	513	15,488	120	450	18,423	549	15,799
Least significant .05	30	774	39	915	—	56	1,139	39	1,094
difference at .01	44	1,113	57	1,337	—	82	1,888	56	1,594
F value for treatments	156.2†	163.2†	97.3†	243.4†	—	17.8†	213.8†	71.3†	150.5†
F required at .05	3.86	3.86	3.84	3.84	—	3.84	3.84	3.84	3.84
F required at .01	6.99	6.99	7.01	7.01	—	7.01	7.01	7.01	7.01

*Applications of P_2O_5 and K_2O with each rate of N on the Chesterfield, Norfolk, Decatur, and Hartsells soils were 100 and 60, 100 and 70, 160 and 67.5, aud 80 and 67.5 pounds per acre respectively.

**The 20-pound rate of nitrogen was not used on Chesterfield soil.

†Highly significant.

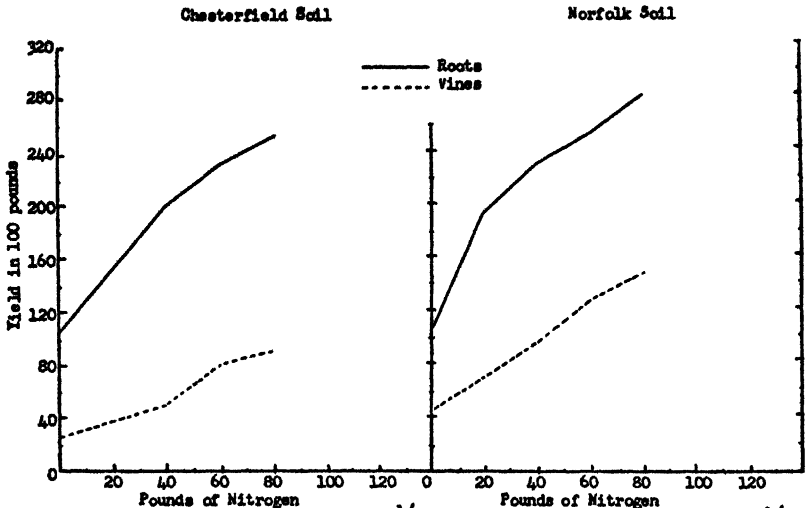
pounds per acre. Each increase in vine yields was highly significant. The difference in root yields was highly significant for each nitrogen increment from 0 to 60 pounds per acre, and was significant for the nitrogen increase from 60 to 80 pounds per acre.

There was a highly significant increase in vine production on Norfolk soil for each increment of nitrogen applied from 0 to 80 pounds per acre. Each increase in yield of roots was highly significant for each nitrogen increment from 0 to 40 pounds per acre, and significant for each nitrogen increment from 40 to 80 pounds per acre.

On Decatur soil the increase in vine production was highly significant for each increment of nitrogen applied from 0 to 120 pounds per acre. There was an increase in yield of roots for each nitrogen increment. Difference in yield of roots was significant for the nitrogen increase from 0 to 30 pounds, but the difference was a little short of significance for the nitrogen increase from 90 to 120 pounds per acre; the increases in root yields from the increases in nitrogen application from 30 to 60 and 60 to 90 pounds per acre were not significant.

On Hartsells soil the increase in vine yields was highly significant for each increment of nitrogen applied from 0 to 120 pounds per acre. Differences in yield of roots were highly significant for nitrogen increases from 0 to 30 pounds and from 30 to 60 pounds per acre; the difference was not significant for the nitrogen increase from 60 to 90 pounds per acre. The yield "leveled off" with the 90 pound rate of nitrogen. The difference in the yield of roots from an application of 90 and 120 pounds of nitrogen per acre was not significant.

Relation of vine yields to root yields is shown in Figs. 1 and 2. Curves represent yields of both vine and roots. Curves in Fig. 1 represent yields from Chesterfield and Norfolk soils and those in Fig. 2 represent yields from Decatur and Hartsells soils. The curves in both figures show that yields were increased by increasing the rates of nitrogen applied. Therefore, the slope of the curves is upward.



Chesterfield Soil

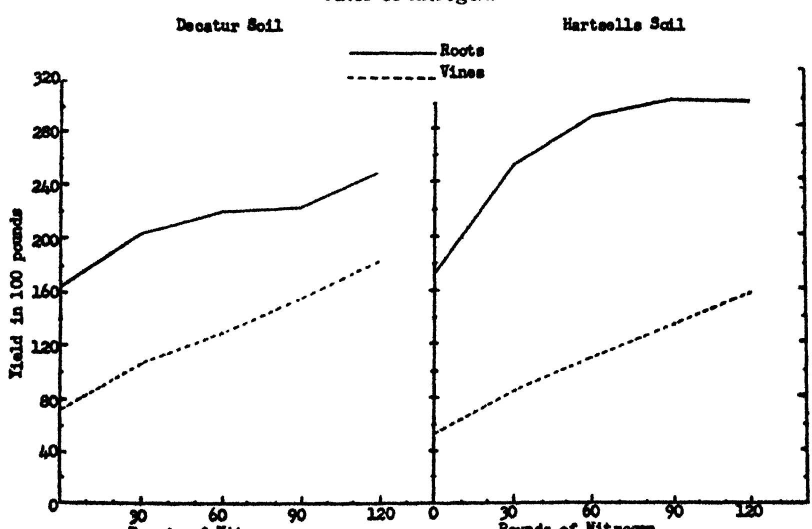
	F found[1]	
	Roots	Vines
Linear regression	37.6	25.8
Quadratic regression	.6	.6

Norfolk Soil

	F found[1]	
	Roots	Vines
Linear regression	115.8	507.9
Quadratic regression	.7	.2

[1] F found by leaving out 0 rate of nitrogen. F required at the .05 level is 6.0 and at the .01 level is 13.7.

FIG. 1. Sweetpotato vine and root yields in different soils with different rates of nitrogen.



Decatur Soil

	F found[1]	
	Roots	Vines
Linear regression	40.0	139.8
Quadratic regression	1.8	.2

Hartselle Soil

	F found[1]	
	Roots	Vines
Linear regression	219.5	599.6
Quadratic regression	64.1	2.1

[1] F required at the .05 level is 5.3 and at the .01 level 11.3.

FIG. 2. Sweetpotato vine and root yields on different soils with different rates of nitrogen.

Analyses of regressions (2) of both roots and vines on rates of nitrogen were made for all soil types to determine whether the trends were linear or quadratic and significant.

The curves representing root yields on Chesterfield and Norfolk soils were found to be significant for quadratic trends because of the low yields produced from the 0-pound rate of nitrogen. The parts of the same curves representing root yields produced from the 40-, 60-, and 80-pound rates on the Chesterfield soil and from the 20-, 40-, and 80-pound rates of nitrogen on the Norfolk soil were found to be highly significant for linear trends. The curves representing vine yields on both soils were found to be highly significant for linear trends. The curves are upward and tend to remain wide apart with the high rates of nitrogen. Therefore, no indication is shown that either vine or root yields have reached a point of "leveling off" or of showing a decrease with increase in nitrogen rates.

On Decatur soil the curves for both vines and roots failed to show significance for quadratic trends. However, both curves were found to be highly significant for linear trends. The curves are upward and tend to come closer together with the high rates of nitrogen. No evidence is shown that the yield of either vines or roots have reached the point of "leveling off". The data do not indicate that further increases in root and vine yields might not be obtained from higher rates of nitrogen applications. This is also shown for Chesterfield and Norfolk soils.

The curve for vine yields on Hartsells soil was found to be highly significant for a linear trend. The curve representing root yields was found to be highly significant for a quadratic trend. A "leveling off" of root yields is shown by the line at the 90-pound rate of nitrogen application on this soil.

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Effects of Organic Materials, Fertilizers, and Irrigation on the Yield of Sweetpotatoes

By L. M. Ware and W. A. Johnson, *Alabama Agricultural Experiment Station, Auburn, Ala.*

High yields must be obtained from crops that are expensive to produce if high returns are to be obtained. The sweetpotato is an expensive crop to produce. Although it is well adapted to the South and high yields may be produced, yields are often low on less productive soils with the usual treatment consisting of 400 to 800 pounds per acre of a commercial fertilizer. The application of a commercial fertilizer is a standard practice; turning under of a legume is a frequent practice; irrigation, however, is a very unusual practice. The studies reported here were designed to determine the value of these several practices.

Results of studies on the use of irrigation and organic materials with a number of vegetable crops have been previously reported (1, 2, 3).

Methods

In 1942, several experiments were started at the Alabama Agricultural Experiment Station to measure the effects of fertilizers, animal manure, green manure, and irrigation on the production of sweetpotatoes. The experiments were conducted in specially constructed bins. The topsoil, to a depth of 10 inches in each set of bins, was intermixed, composited, and equally distributed among the bins in a series. The bins were open beneath, thus allowing the composited topsoil to rest on the undisturbed subsoil.

The soil used in the study of animal manure and vetch was a sandy loam belonging to the Chesterfield series, and the soils used in the studies of irrigation and legumes and with the vetch and nitrogen studies were sandy loam soils belonging to the Norfolk series.

Results

The results are presented in three tables. There is no direct relation between the results reported in the three separate tables.

Effects of Fertilizers, Animal Manure, and Vetch on Yields

In this study, two rates of fertilizer consisting of 800 and 1200 pounds per acre of a 4–10–7 grade were used. At each rate of fertilizer application, treatments were given consisting of no manure added, 6 tons per acre of animal manure added, and 6 tons of green vetch added. At the higher rate of fertilizer application, one treatment consisting of 12 tons of stable manure, was added. Both the Porto Rico and the Triumph varieties were used in the study. The results are presented in Table I.

Effects of Fertilizers on Yields:—Without manure or vetch added, the yield of No. 1 Porto Rico potatoes from the 1200 pounds per acre

TABLE I—YIELD OF SWEETPOTATOES RECEIVING MANURE AND VETCH WITH DIFFERENT RATES OF FERTILIZER

Fertilizer Per Acre 4-10-7 (Lbs)	Manures Applied Per Acre (Tons)		Yields Per Acre (Bushels)		
			5-Year Average		6-Year Average
			Porto Rico		Triumph
	Animal	Green†	No. 1's	Total‡	Total‡
800	0	0	140	224	217
800	6	0	211	338	344
800	0	6	168	312	321
1,200	0	0	154	270	275
1,200	6	0	191	372	355
1,200	0	6	177	346	348
1,200	12	0	184	445	426
Least significant difference at .05 level			28.4	47.1	31.1
Least significant difference at .01 level			43.1	71.3	41.9
F values obtained for treatment			8.33*	27.25**	37.63**
F values required at .05 level			4.28	4.28	4.28
F values required at .01 level			8.47	8 47	8.47

*Significant.
**Highly significant.
†Green vetch introduced and turned.
‡Includes all sound potatoes.

of fertilizer was only 14 bushels per acre more than from the 800-pound application. This increase was much below significance at the .05 level. However, the increase in the total yield of the Porto Rico variety was 46 bushels for the extra fertilizer and of the Triumph 58 bushels per acre. The increase of 46 bushels was just below significance; the increase of 58 bushels was highly significant.

Effects of Animal Manure on Yields: Increases in the yield of No. 1 potatoes of the Porto Rico variety and in the total yield of both varieties resulting from the addition of 6 tons per acre of animal manure were significant or highly significant at both rates of fertilizer application. At the lower fertilizer rate, the increase in the yield of No. 1 Porto Rico potatoes from the 6 tons of manure per acre was 71 bushels; the increase in the total yield per acre of the Porto Rico variety was 114 bushels per acre and of the Triumph variety 127 bushels. At the higher fertilizer rate the increase in the yield of No. 1 Porto Rico potatoes from 6 tons of manure per acre was 37 bushels per acre; the increase in total yields per acre of the Porto Rico variety was 102 bushels and of the Triumph 80 bushels per acre.

At the higher rate of fertilizer application, increasing the manure from 6 to 12 tons per acre resulted in no increase in the yield of No. 1 Porto Rico potatoes but gave an increase of 73 bushels in the total yield of the Porto Rico variety and of 71 bushels in the total yield of the Triumph variety. Both increases were highly significant.

There was no significant difference in the yield of either variety from 1200 pounds of a fertilizer and 6 tons of animal manure and from 800 pounds of fertilizer and 6 tons of animal manure per acre.

The total yield and the yield of No. 1 potatoes of the Porto Rico variety and the total yield of the Triumph variety were significantly higher from 800 pounds of fertilizer and 6 tons of animal manure than from 1200 pounds of fertilizer without animal manure. These differ-

ences amounted to 57 bushels per acre in the yield of No. 1 Porto Rico potatoes and to 68 bushels and 69 bushels per acre in the total yields of the Porto Rico and the Triumph varieties, respectively.

Effects of Green Manure on Yields:—The turning under of vetch gave increases in yield of No. 1 Porto Rico potatoes just a little below significance at both the lower and the higher rates of fertilizer applications. The increases in the total yields of potatoes of both varieties at both rates of fertilizer application were highly significant. These increases ranged from 73 to 104 bushels per acre.

At the lower fertilizer rate, the 6 tons of animal manure added gave a highly significant increase in the yield of No. 1 Porto Rico potatoes over the 6 tons of green manure added but failed to give a significant increase at the higher fertilizer rate. The differences in the total yields were not significant at either rate for either variety.

Effects of Irrigation and Organic Matter on Yields

In this study, two rates of fertilizer consisting of 500 and 1000 pounds per acre were used. At each rate of fertilizer application, four treatments were given. The first treatment received no irrigation and no organic matter, the second received organic matter but no irrigation, the third received irrigation but no organic matter, and the fourth received both irrigation and organic matter. The irrigation consisted of the application of 1 inch of water each week rainfall was not approximately this amount. The organic matter added consisted of 2 tons dry Lespedeza stems applied in February and 6 tons green Crotalaria applied in late fall. The results are presented in Table II.

Effects of Irrigation on Yields:—At the lower fertilizer rate and without the addition of a legume, irrigation increased the yield of No. 1 potatoes only 14 bushels per acre and the total yield only 45 bushels; both increases fell below significance. At the higher fertilizer rate,

TABLE II—Yield of Sweetpotatoes Receiving Legumes and Irrigation — Porto Rico Variety

Fertilizer Per Acre 6-8-4 (Lbs)	Organic	Irrigation Amount Per Week** (Ins)	Yields Per Acre (Bushels) 3-Year Average	
			No. 1's	Total
500	O	0	156	232
500	L*	0	220	352
500	O	1	170	277
500	L*	1	278	399
1,000	O	0	199	309
1,000	L	0	230	383
1,000	O	1	241	373
1,000	L	1	293	415
Least significant difference at .05 level			42.0	56.6
Least significant difference at .01 level			58.0	78.4
F values obtained for treatments			12.09†	12.06†
F values required at .05 level			2.77	2.77
F values required at .01 level			4.28	4.28

*Treatment consists of 2 tons dry Lespedeza sericea applied in winter and 6 tons of green Crotolaria spectabalis applied in the fall.
**One inch of water applied per week if rainfall did not supply this much.
†Highly significant.

irrigation increased the yield of No. 1 potatoes 42 bushels and the total yield 64 bushels; both increases were significant at the .05 level.

Where both a legume and irrigation were added, irrigation increased the yield of No. 1 potatoes 58 bushels at the lower fertilizer rate and 63 bushels per acre at the higher fertilizer rate. Both of these increases were highly significant. The increases in the total yield were only 47 bushels at the lower fertilizer rate and only 32 at the higher rates; both of the increases were below significance. This greater increase in the yield of No. 1 than in the total yield by irrigation means that irrigation reduced the potatoes in the lower grades by changing them to the No. 1 grade. This was true for irrigation when applied in combination with a legume; it was not true when applied without a legume.

Effects of Legumes on Yields:—Legumes have given much larger increases in yields than irrigation. At the lower fertilizer rate and without irrigation, legumes increased the yield of No. 1 potatoes 64 bushels and the total yield 120 bushels per acre; both of the increases were highly significant. At the higher rate, the legume increased the yield of No. 1 potatoes 31 bushels and the total yield 74 bushels per acre. The increase in No. 1's was not significant; however, the increase in total yield was significant.

Where irrigation was applied in combination with the legume, the legume increased the yield of No. 1 potatoes at the lower fertilizer rate 108 bushels and the total yield 122 bushels per acre. These differences were both highly significant. At the higher fertilizer rate, the legume increased the yield of No. 1 potatoes 52 bushels and the total yield 42 bushels per acre.

Effects of a Combination of Legumes and Irrigation on Yields:—The use of both legumes and irrigation increased the yield of No. 1 potatoes and the total yield. The increase in the yield of No. 1 potatoes was 122 bushels and in the total yield was 167 bushels per acre at the lower fertilizer rates; at the higher fertilizer rate, the increases were 94 and 106 bushels per acre. These differences were highly significant.

Adequacy of Winter Legumes to Supply Nitrogen

In this study two complete series of treatments were given, one with and one without vetch. In each series nitrogen rates were varied in 2 per cent increments from 0 to 8 per cent in a base application of 1000 pounds of a X–10–7 fertilizer. The experiment extended over a 4-year period. The Porto Rico variety was used. The results are presented in Table III.

The yield of No. 1 potatoes from a 0 application of nitrogen with vetch was 265 bushels and from 40 pounds per acre of nitrogen (4 per cent nitrogen) without vetch was 271 bushels per acre; the total yields for these two treatments were 432 bushels and 412 bushels per acre, respectively. The vetch, therefore, produced yields approximately equivalent to 40 pounds of nitrogen.

On plots receiving vetch, a significant increase in the yield of No. 1 potatoes was obtained from 80 pounds per acre of nitrogen over

TABLE III—Yields of Sweetpotatoes from Different Amounts of Nitrogen With and Without Vetch (Auburn Bins)

Fertilizer Formulae (1,000 Pounds Per Acre)	Yields Per Acre (Bushels) 4-Year Average With Vetch No. 1's	With Vetch Total**	Without Vetch No. 1's	Without Vetch Total**
0-10-7	265	432	132	203
2-10-7	269	429	245	349
4-10-7	307	462	271	412
6-10-7	280	466	295	455
8-10-7	336	517	330	505
Least significant difference at*.05 level			57.7	63.1
Least significant difference at* .01 level			77.9	85.4
F values obtained for treatments*			8.35†	17.38†
F values required at .05 level			2.25	2.25
F values required at .01 level			3.14	3.14

*Statistically analyzed as 10 treatments—5 with vetch and 5 without vetch.
**Sound potatoes.
†Highly significant.

either 0 or 20 pounds per acre although the increases in yield were not significant for the intermediate increases in nitrogen. The increase in the total yield of potatoes from 80 pounds per acre of nitrogen over the 0 and 20 pounds per acre of nitrogen was highly significant on the vetch plots. Other increases in nitrogen failed to give significant increases in yields.

On plots not receiving vetch, highly significant increases in the yield of No. 1 potatoes were obtained by increasing the nitrogen from 0 to 20 pounds and from 20 pounds to 80 pounds per acre. The increases in the yield of No. 1 potatoes for increases in nitrogen from 20 to 40, from 40 to 60, and from 60 to 80, while consistent, were below significance at the .05 level.

Highly significant increases in total yields were obtained by increasing the nitrogen from 0 to 20 pounds, from 20 to 60 pounds, and from 40 to 80 pounds per acre on plots not receiving a legume. The differences in total yield of potatoes not receiving vetch were not significant between plots receiving 40 and 60 pounds and between those receiving 60 and 80 pounds per acre of nitrogen although the increases in yield were consistently higher from each higher nitrogen application.

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Effect of Length of Exposure to Sun on Keeping of Sweet Potatoes

By Charles A. Miller and W. D. Kimbrough, *Louisiana Agricultural Experiment Station, Baton Rouge, La.*

It is generally recognized that Irish potatoes dug in hot weather and exposed to the sun for a relatively short time are subject to sunscald. Potatoes so injured are subject to severe losses in transit or storage. For this reason growers are careful not to expose potatoes dug in hot weather to the sun any more than can possibly be helped. Many publications dealing with the harvesting of sweet potatoes, as Lutz and Simons (1), make the statement that sweet potatoes dug during hot weather should not be left exposed for more than a few minutes because of the danger of sunscald. Experimental evidence on the duration of exposure to the sun necessary for injury was not found. The work here reported was conducted to get some information on this subject.

Plants from certified Porto Rico potatoes were used in this experiment. Plantings were made at three different times May 9, May 26, and June 12, 1947 so as to have roots of marketable size ready to harvest from August through October. A preliminary digging was made August 1 and regular diggings August 12 and 26, September 2 and 17, and October 9. Days for digging were picked when it was thought that there would be no rain. The 1947 season was an excellent one for this test as it was very hot and dry. So that the roots would be exposed during the time when the sun and high temperatures would likely do the most damage, diggings were started promptly at 10:00 a m, except for the one on September 2 when digging began at 1:00 p m. Extreme care was used in handling the roots. After they were dug the roots were left on the surface of the soil for various exposures to sunlight and prevailing weather conditions. The regular periods of exposure used were 1 hour, 3 hours, 6 hours, 1 day, 3 days and 1 week. At the August 12th digging exposures of 15 and 30 minutes were added, and at the September 2 digging periods of 30 minutes and 2 hours were used with 3 hours being the maximum exposure. At each digging time one lot of potatoes, to serve as a check, was picked up immediately after the roots were plowed out. Air temperatures 4 inches above the soil and soil temperatures 4 inches below the surface were recorded each time the roots were picked up to be taken to the storage house. The thermometers in the air were not exposed directly to the sun, nor was the mercury column of soil thermometer turned toward the sun. The lots of potatoes were removed from the field to a storage house. They were kept in storage for 2 weeks then examined for breakdown and the sound potatoes put back into storage.

The results obtained are given in Tables I and II. The data show that the roots were not damaged due to exposure to the sun when the interval was less than 3 hours. The damage at the 3-hour interval was variable and not as much as periods of longer duration. There were no appreciable differences due to exposure intervals of 6 hours and 1 day. This might be expected because the 6-hour interval included the

TABLE I—EFFECT OF EXPOSURE TO SUN ON THE KEEPING OF SWEET POTATOES TWO OR MORE WEEKS AFTER HARVEST

Length of Exposure	Date of Harvest											
	Aug 1		Aug 12		Aug 26		Sept 2		Sept 17		Oct 9	
	Weight (Lbs)	Sound (Per Cent)	Weight (Lbs)	Sound (Per Cent)	Weight (Lbs)	Sound (Per Cent)	Weight (Lbs)	Sound (Per Cent)	Weight (Lbs)	Sound (Per Cent)	Weight (Lbs)	Sound (Per Cent)
Check	40	100	40	100	42	100	34	100	41	100	82	100
30 minutes	—	—	38	100	—	—	36	100	—	—	—	—
1 hour	42	100	43	100	45	100	31	100	79	100	80	100
2 hours	—	—	—	—	—	—	50	100	—	—	—	—
3 hours	44	100	35	76	46	100	48	80	78	96	86	100
6 hours	39	64	38	53	83	93	—	—	90	78	84	100
1 day	—	—	41	54	79	94	—	—	88	81	82	100
3 days	—	—	37	32	74	49	—	—	119	46	122	100
1 week	—	—	30	26	107	47	—	—	129	35	124	92

TABLE II—TEMPERATURE RECORDS (DEGREES F) AT THE TIME OF REMOVING SWEET POTATOES FROM THE FIELD

Length of Exposure	Date of Harvest									
	Aug 12		Aug 26		Sep 2		Sep 17		Oct 9	
	Air Temp	Soil Temp	Air Temp	Soil Temp	Air Temp	Soil Temp	Air Temp	Soil Temp	Air Temp	Soil Temp
Check	98.6	92	100.4	88	104.0	102	107.6	88	95.0	80
30 minutes	99.5	92	—	—	107.6	104	—	—	—	—
1 hour	102.2	94	102.2	90	105.8	104	107.6	92	96.8	84
2 hours	—	—	—	—	102.4	102	—	—	—	—
3 hours	107.6	102	104.0	98	102.4	100	107.6	96	93.2	88
6 hours	86.0	92	89.6	96	—	—	98.6	100	89.6	86
1 day	105.8	90	102.2	92	—	—	102.2	92	95.0	78
3 days	96.8	92	111.2	92	—	—	84.2	84	91.4	76
1 week	102.2	95	96.8	94	—	—	86.0	94	102.2	89

most severe conditions in a day. Damage to sweet potatoes due to exposure after digging was more severe in August and September than in October. This can probably be explained on the basis of difference in temperature. The temperatures recorded in Table II, taken when the lots of potatoes were removed from the field, are only indicative because no continuous record was made. The breakdown does, however, appear to be correlated to some extent with high temperature.

Apparently all of the breakdown due to exposure after digging occurred in the first 2 weeks in storage, as there was no further loss with continued storage. Examinations were made after 30 and 60 days.

At the time the 1-day exposure lots were removed from the field no visible injury could be detected and all roots appeared to be sound. After 3 days of exposure, injured areas were very prominent on the sweet potatoes. Injury to the roots was found on the surface most directly exposed to the sun. During the early stages the injured or sunscalded areas were rather small, irregular in shape and brownish in color. These areas enlarged rapidly in storage and in 10 to 15 days rot had penetrated throughout the roots. A few days after the rot had set in, the tissues would change from to a very dark brown or black

color. On casual observation it appeared to be quite similar to black rot.

That sweet potatoes of the Porto Rico variety may be injured by exposure to the sun when they are dug in hot weather has been definitely shown. Sweet potatoes are, however, not as likely to be injured by sunscald as Irish potatoes, as an exposure of approximately 3 hours under severe condition was necessary to cause noticeable injury. This does not mean that early sweet potatoes should be neglected at digging time and unnecessarily exposed to the sun during the hottest part of the day. It does mean that sweet potatoes can be dug easily without damage from sunscald. It does not seem likely that sweet potatoes dug in October will be injured by sunscald.

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The Occurrence of Bacterial Soft Rot on Potatoes Resulting from Washing in Deep Vats

By D. H. Dewey and W. R. Barger, *U. S. Department of Agriculture, Fresno, Calif.*

The dumping of new potatoes directly from trucks and trailers into deep water vats has been used in Kern County, California, for several years to facilitate handling at the packing shed. This new method, which eliminates the handling and dumping of field sacks at the shed, was claimed to be responsible for heavy transit losses due to tuber breakdown in 1946. The poor condition of the tubers upon arrival at market apparently resulted from their submersion in water, since that was the only essential divergence from the handling method previously used. The bulk handling vats were 8 to 12 feet deep and large enough to hold several truck or trailer loads at once. They were constructed with the sides sloping to the bottom to feed the potatoes to an elevating conveyor connecting the vat to the grading belt. The vats were filled with water, and the potatoes were dumped directly into them by lifting one side of the field conveyance as shown in Fig. 1.

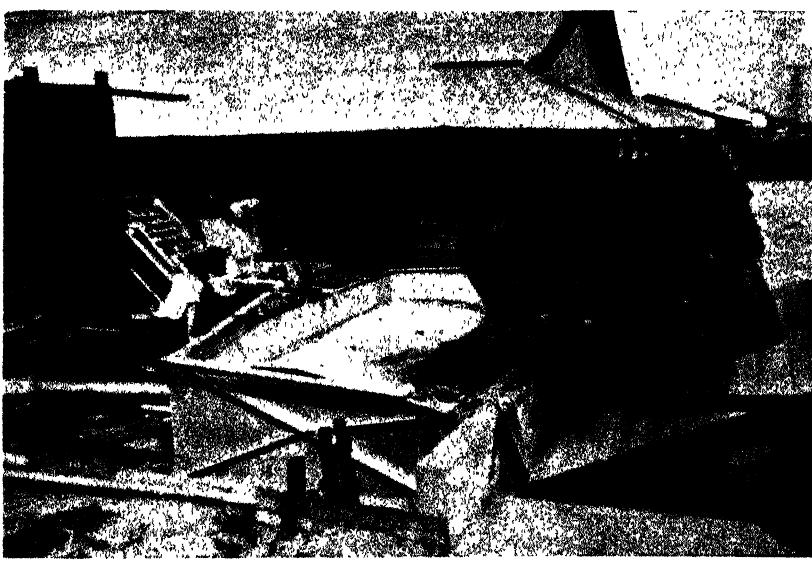

Fig. 1. Bulk handling vat at Edison, California. After being dumped from the truck into the water, the tubers are removed from the bottom of the vat by the elevator shown at the left center of the photograph. They are then conveyed into the packing shed in the background.

The type of decay accompanying the tuber "breakdown" in the 1946 shipments was not identified, but reports of the condition of the tubers upon arrival at market indicated that it was bacterial soft rot. If so, the work of other investigators shows that submerging the tubers in water during packing operations was likely a contributing

factor. Ruehle (4) found that wash water spreads the inoculum causing bacterial soft rot of potatoes and furnishes the moisture necessary for growth of the bacteria *(Erwinia carotovora)*, and that washing the tubers in tubs was more conducive to spread of the disease than washing with a spray of fresh water. He also reports that soft rot infection may start at the lenticels and that it has been observed on new tubers taken from a water-logged soil. Smith and Ramsey (6) have studied the lenticels of the potato as avenues of infection for bacterial organisms and found that immersing tubers in water suspensions of bacteria for as short a period as 1 minute resulted in lenticel infection when the tubers were held in a moist chamber at 72 degrees F for 48 hours following treatment.

Laboratory Test

A preliminary test was conducted in the laboratory to determine the relationship between the incidence of bacterial soft rot infection of tubers following their submersion in contaminated water and the external hydrostatic pressure, and to determine if sun heat and mechanical injuries of the tubers were contributing factors toward infection under these conditions.

Methods and Materials:—Potato tubers of the White Rose variety and of B size which were harvested, washed, and graded in the ordinary commercial manner by a shipper at Edison, California, were used for the seven treatments outlined in Table I. Each treatment consisted of four replications of 100 tubers each.

Hydrostatic pressure was obtained by applying air pressure to shallow closed chambers in which the tubers were covered by a suspension in water of bacterial soft rot material obtained from decayed stock. The chambers were left open for 0 pounds pressure so that the suspension was at atmospheric pressure. The control or "check" tubers were submerged in tap water.

Sun injury was induced by spreading the tubers on a greenhouse bench for 4 hours. The tubers were in the direct sunlight as transmitted through the glass, and temperatures of 100 to 105 degrees F were measured at their centers. Other tubers were mechanically injured by scraping one side over a household vegetable grater in such way as to make wounds approximately 1 inch in diameter on the tuber surface.

After the tubers were submerged for 1 hour they were placed in burlap sacks and stored for 6 days under moist burlap at 78 degrees F and 90 per cent relative humidity. During this incubation period the infected tubers were discarded as soon as bacterial soft rot became evident.

The accumulated number of infected potatoes of each replication were calculated as the percentage of the total number of tubers. These data were then transformed (5) from percentage to angular degrees by the formula, angle $=$ arc sin $\sqrt{\text{percentage}}$, and subjected to the analysis of variance.

Results:—The summarized results of the laboratory test are pre-

sented in Table I. By comparing the percentage of rot infection in lots of potatoes subjected to 0 and to 5 pounds per square inch pressure it may be seen that hydrostatic pressure was of definite influence, provided the tubers were not otherwise predisposed to soft rot infection by exposure to high temperatures. In the uninjured lots, the mean percentage of potatoes with soft rot varied from 2.2 per cent to 23.3 per cent as pressure varied from 0 to 5 pounds, and a similar large and positive difference resulted from pressure differences in the mechanically injured treatments.

TABLE I—THE INFLUENCE OF SUBMERGING POTATO TUBERS IN THE LABORATORY ON THE INCIDENCE OF BACTERIAL SOFT ROT INFECTION

Condition of Tubers	Solution	Air Pressure* (Lbs)	Mean Infection**	
			Angle†	Percentage‡
Uninjured	Inoculum	0	8.50	2.2
Uninjured	Inoculum	5	28.83	23.3
Sun-injured	Inoculum	0	43.87	48.0
Sun-injured	Inoculum	5	40.03	41.4
Mechanically-injured	Inoculum	0	3.47	0.4
Mechanically-injured	Inoculum	5	17.94	9.5
Uninjured (check)	Tap water	0	8.00	1.9
Significant difference	———	–	3.55	—
Observed F	———	–	24.01§	—

*Air pressure in addition to atmospheric pressure upon the solution.
**Incubation period of six days duration.
†Angle = arc sin $\sqrt{\text{percentage}}$.
‡Determined from the mean angle.
§Odds against the difference noted being due to chance are greater than 99:1.

The greatest amount of soft rot occurred on sun-injured tubers and the effect of injury apparently overshadowed the effect of pressure. The small amount of decay on mechanically-injured tubers indicated that this type of injury was not a contributing factor to the infection of submerged tubers.

FIELD TEST

The effect of submerging potatoes in water upon the subsequent incidence of infection with bacterial soft rot was studied further in an experiment conducted at a potato shed at Shafter, California. A vat used commercially for bulk handling of potatoes was available, and comparisons of the amount of soft rot infection of tubers held at several depths of water for ½ and for 1 hour were made.

Materials and Methods:—Size B potatoes of the variety White Rose which had been previously washed, graded, and prepared for commercial shipment were used in this study. Four 50-pound lots of tubers were weighed and bagged for each treatment and four or five tubers seriously infected with bacterial soft rot were added to each lot except those to be held as checks. The bulk handling vat was filled with fresh water (temperature 76 degrees F) and the tubers were submerged and treated simultaneously as follows:

1. One hour below the water surface at an average depth of approximately 1 foot.

2. One hour at an average depth of 5 feet of water.
3. One hour at an average depth of 10 feet of water.
4. One-half hour at an average depth of 10 feet of water.
5. Check, tubers dipped at water surface until thoroughly wet to simulate ordinary washing.

The four lots of each treatment were then taken from the vat and the tubers previously added as a source of inoculum were removed. The potatoes were loaded into a closed-body truck, covered with moistened burlap and hauled to the laboratory at Fresno where they were stacked at random in the incubation room and covered with moistened burlap. Final counts of the tubers definitely infected with bacterial soft rot were made on the third day of incubation. The data were converted to percentage of diseased tubers on the basis of total tubers per replication, transformed to angular degrees, and treated statistically by the analysis of variance.

Results:—When the potatoes were inspected marked differences in the percentage of tubers infected with soft rot were noted. The number used for each replication and the mean percentage of total tubers infected with soft rot are given in Table II together with the transformed means and their statistical comparison.

The potatoes of the check treatment which simulated ordinary washing had significantly less soft-rot infection than the other treatments. The tubers submerged for 1 hour at either 1 foot or 5 feet had twice the amount of infection as the checks, and those submerged for 1 hour at 10 feet had four times as much infection. The effect of length of time of submersion was shown by a significant difference in infection of tubers held for 1 hour and for ½ hour at a depth of 10 feet. The 1-hour treatment resulted in more infection than the ½-hour treatment, the difference being 6.1 percentage points.

TABLE II—THE INFLUENCE OF SUBMERGING POTATO TUBERS IN WATER ON THE INCIDENCE OF BACTERIAL SOFT ROT INFECTION AT SHAFTER, CALIF. (1947)

Submersion Time and Depth		Replication				Mean Infection*	
		1	2	3	4	Angle**	Percentage†
1. 1 hour..... 1 foot.....	Total number of tubers Percentage of infected tubers	388 8.8	395 6.1	380 11.1	369 7.9	16.84	8.4
2. 1 hour..... 5 feet.....	Total number of tubers Percentage of infected tubers	383 5.5	365 9.9	370 12.7	393 6.4	16.86	8.4
3. 1 hour..... 10 feet.....	Total number of tubers Percentage of infected tubers	382 11.0	372 29.3	388 10.3	381 17.9	23.97	16.5
4. ½ hour..... 10 feet.....	Total number of tubers Percentage of infected tubers	384 11.2	380 9.0	386 12.4	377 9.3	18.85	10.4
5. Check..... Washed only..	Total number of tubers Percentage of infected tubers	389 3.1	361 3.9	361 5.3	394 5.1	11.97	4.3
Significant difference.....						2.33	—
Observed F.....						5.53‡	—

*Incubation period of 3 days duration.
**Angle = arc sin $\sqrt{\text{percentage}}$.
†Determined from the mean angle.
‡Odds against difference noted being due to chance are greater than 19:1, less than 99:1.

The depth to which the tubers were submerged in the water was also important in respect to subsequent infection for comparisons of treatments 1, 2, and 3, in which the tubers were in the vat for the same length of time, show that more infection resulted following submergence at 10 feet than at either 5 feet or 1 foot. However, the difference in percentage of infection resulting on tubers held at 5 feet and 1 foot was practically nil.

Discussion

The bacterial soft rot infection observed in these tests originated primarily at the tuber lenticels and the symptoms agreed with those described by Smith and Ramsey (6). Water-soaked and slightly darkened areas around the lenticels appeared first, and as infection advanced these areas coalesced so that the individual lenticel infections could not be distinguished. The breakdown of the tubers in many instances was rapid, and at the time of inspection the decayed tissue had become whitish or creamy, very soft, somewhat watery and even slimy so that surrounding tubers had become wet. The economic importance of bacterial soft rot is considerable since it was found to be the most important cause of decay in carloads requiring reconditioning at the Chicago Produce Terminal, ranging from 2 to 98 per cent in the cars examined in 1942 (6). Although the "breakdown" reported in the 1946 Kern County shipments was not proved to have relationship to the incidence of soft rot infection, it is quite probable that soft rot was the causal factor. The increased infection resulting from submersion of the tubers in these tests indicated that the ordinary amount of infection would be increased by the use of vats for bulk handling at the shipping point, and that excessive amounts of resultant decay might be present upon arrival at the receiving point.

The application of hydrostatic pressure in the laboratory test was of similar effect upon soft rot infection as submersion of the tubers in the vat test. In both tests, the resulting soft rot infection was significantly greater at the simulated and actual depths of 10 feet than at the surface. For depth of submersion or increased pressure to become an important factor it apparently must be greater than 5 feet or 2½ pounds per square inch. The percentage of infected tubers was the same at depths of 1 and 5 feet but increased greatly at a depth of 10 feet.

The length of time during which the tubers were submerged in water also influenced the incidence of soft rot infection since those submerged in the vat at a depth of 10 feet for 1 hour became more seriously infected than those held at that depth for ½ hour. Likewise, the tubers submerged in water only long enough to become wet had considerably less infection than those held just beneath the surface for 1 hour. It is evident that tubers that are not quickly removed from the soaking vat are most likely to rot and become a source of infection for healthy tubers during the transit and marketing period. Some potatoes may become lodged in a vat for a long time. Marked tubers were dropped into a bulk handling vat during a period of commercial operation. Some failed to reappear until the vat was emptied during

a shutdown several hours later. To prevent the potatoes from being in the water too long, it would be advisable to run small quantities at a time, "cleaning up" between lots.

Some packing-shed operators have expressed the view that mechanical injury of tubers due to bulk handling was responsible for increased decay. This view is not supported by the preliminary test as an increase in the amount of infection of tubers which were mechanically injured by artificial means did not occur. There was, instead, a decrease in the amount of decay which cannot be accounted for and may have fortuitously occurred since this test was not repeated.

An excessive quantity of decay following sun injury of the tubers was anticipated. As reported by other workers (1, 2, 3), freshly dug immature potatoes may be injured by exposure to sun and heat if the temperature of the potato tissue reaches approximately 110 degrees F, and thus become readily susceptible to soft rot infection.

The large amount of rot infection originating at the lenticels indicates that submerging the tubers in water forced the entrance of moisture and bacteria into the lenticels and favored infection.

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Observations on Another Species of Cultivated Pepper, Capsicum pubescens R. & P.

By CHARLES B. HEISER, JR., *Indiana University, Bloomington, Ind.*, and PAUL G. SMITH, *University of California, Davis, Calif.*

IN recent years all of the cultivated peppers have been considered as constituting a single species, *Capsicum frutescens* L. (1, 6, 7). During the past several years peppers from a variety of sources have been grown at the Agricultural Experiment Station at Davis, California in a breeding program for disease resistance. Among the peppers grown was a form bearing the name *"chile mañsana"* which was secured from seed brought from Mexico in 1938 by the late Professor J. W. Gilmore. The seed packet was marked as coming from San Juan Ixcoy, Guatemala. Inasmuch as Professor Gilmore was not in Guatemala at that time, the actual collector is not known.

These plants proved to be quite different from any variety of *Capsicum frutescens* known to us. A description to fit the plants could not be found in Irish's monograph (11), the most complete treatment of its kind. Bukasov's (3) work on the cultivated plants of Mexico, Guatemala, and Colombia was consulted, and our pepper was found to agree closely with the description given for *C. pubescens* R. & P. This cultivated pepper was found by the Russian expedition in both Guatemala and Colombia and is maintained as a distinct species (3).

Capsicum pubescens was originally described by Ruis and Pavón (12) from plants cultivated in Peru. We have not seen the type. These authors also recognized *C. frutescens,* and give the common name of *"Arnoaucho"* and *"Aji Arnaucho"* for it and *"Roccoto"* for *C. pubescens*. In the account of their travels Ruiz (13, p. 176) writes that both *C. frutescens, ("Arnaucho")* and *C. pubescens* ("Roccoto") are abundant in Peru.

The latter species appears to be a little known one. In addition to the work of Bukasov and the reference cited by him, only a few other obscure references pertaining to this species have been found. Weberbauer (14) mentions *Capsicum* as a plant of the Peruvian Andes without giving species under the common names of "aji," "ucha," and "rocoto". Herrera (8, 9) also gives the common name, "rocoto" for a cultivated pepper of Cuzco, Peru, referring it to *Capsicum sp.* Later (10) he definitely assigns it to *C. pubescens* and distinguishes four varieties, and states that the species is native to the Andes of Peru. It may be significant that Herrera fails to include *C. frutescens.* Either this species is unknown for that region, or he has in some way confused the two. For Central America we have been able to locate only one additional reference. Bravo (2) writes that in Tucuba, D. F. (Mexico) a pepper has been cultivated whose characters agree with those of *C. pubescens,* although it departs from it a little in the nature of the fruit.

Irish (11) lists *Capsicum pubescens* R. & P. among those species which apparently are not in cultivation in Europe or the United States and which he had not seen or could not place on the basis of the de-

scription. It should also be mentioned that the name *C. pubescens* was used in manuscript by Dunal for another species, but this was later changed to *C. chlorocladum* (5). The latter species is placed in synonymy under *C. frutescens* var. *baccatum* by Irish.

From the foregoing survey of the literature it would appear that *Capsicum pubescens* was known from Guatemala, Colombia, Peru, and perhaps Mexico. Several herbaria in this country were consulted for material of this species, and we were fortunate in locating seven specimens at the Chicago Museum of Natural History. These specimens, all annotated as *C. pubescens,* were collected in Mexico, Guatemala, and Honduras.[1] We have not seen any material from Peru. Two specimens from the United States National Herbarium tentatively identified as *C. pubescens* proved upon examination to be varieties of *C. frutescens.*

Morphologically *Capsicum pubescens* has few distinctive features. The plant is, of course, characterized by the presence of a conspicuous pubescence, but several varieties of *C. frutescens* are also pubescent. The leaves of *C. pubescens* are dull and tend to a slight "savoying" between the veins; *C. frutescens* possesses leaves which are smooth and shiny even in the pubescent forms. The corolla lobes of *C. pubescens* are blue or purple in color (Fig. 1, B), but again this character is found in certain varieties of *C. frutescens,* for example, "Black Nubian" (11), and "Japanese Ornamental" (7). The corolla of *C. pubescens,* however, has more distinct folds between the petals than that of *C. frutescens,* and in bud the corolla lobes do not join at the top, leaving a small hole at the top of the unopened corolla (Fig. 1, D). The filaments of the stamens are distinctly more slender and delicate than in any varieties of *C. frutescens* seen by us. Nectaries are present at the base of the corolla lobes, and both colorless and light yellow types have been observed. The nectaries in *C. frutescens* are colorless. Bukasov (3) describes the seeds of *C. pubescens* as black and peculiarly curved. The seeds of the specimens that we have seen are dark, either purple or nearly black, and are also "peculiarly curved" or wrinkled, a character which may prove unique to this species (Fig. 1, C). *Capsicum guatamalense* is also known to have black seeds (3). The fruit of *C. pubescens,* according to Bukasov (3), is red at maturity, whereas those grown by us could more aptly be described as yellow or orange. The fruits are from 1 to 1½ inches in

[1]Collection data on these specimens are as follows:

Mexico: Federal District: El Rosario, 23 August 1936, *MacDaniels 698.*

Guatemala: Alta Verapaz, vicinity of Cobán, alt. about 1300 m., "*chile garrapata,*" March 23–April 19, 1941, *Standley 91227;* San Marco's: vicinity of town of Tajumulco, alt. 2300–2800 m., "*chile cuadro caldo*" also "*chile caballo,*" 28 Feb. 1940, *Steyermark 36930;* Chimaltenango: Fuicala Alameda, near Chimaltenango, alt. about 1830 m., 11–22 Dec. 1940, *Standley 80793;* Solalá. shores of Lago de Atitlán by San Pedro, alt. 1800 m., June 1942, *Steyermark 47273.*

Honduras: Morazán: Zamorano, alt. 800 m., "*chile petenero,*" 30 May 1945 and 22 Aug. 1945, *Rodriguez 3039* and *3237.*

All of these specimens appear to be typical of *Capsicum pubescens* with the exception of *Steyermark 47273* which differs chiefly in the pointed rather than blunt tipped fruit and the more dense pubescence of the stem. Hence this specimen is only tentatively assigned to *C. pubescens.*

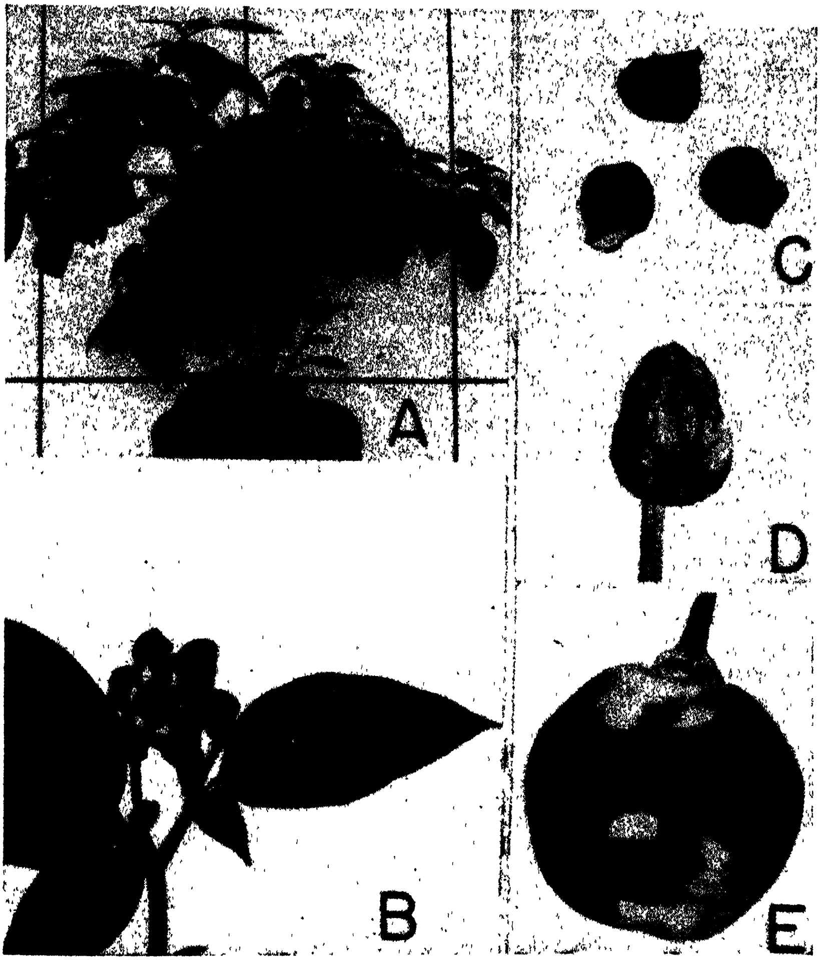

FIG. 1. A, Plant of *Capsicum pubescens* (lines are at 1-foot intervals). B, Flower and leaves (approximately natural size). C, Seeds (×2.5). D, Flower bud (slightly enlarged). E, Fruit (approximately natural size).

diameter (Fig. 1, E), moderately pungent, and with moderately thick walls which are quite watery. Both red and yellow mature-fruit colors and pungent and non-pungent forms occur in *C. frutescens*.

The characters of the pubescence, leaves, corolla, and seeds, in combination, rather readily distinguish this pepper from any of the varieties of *Capsicum frutescens* known to us or any of those described by Irish (11). Unfortunately, Irish gives little or no description of the seeds in his monograph.

Capsicum pubescens may also differ from *C. frutescens* in its response to length of day. For the past several years it has been noted that the former species does not produce flowers during the winter

months under greenhouse conditions. Plants growing vigorously cease flowering about the latter part of October and do not produce flowers again until sometime in March. Since it was desirable to have flowers for pollination purposes, early in January two plants were given supplementary light from a pair of fluorescent lights to make a day length of 12 to 12½ hours. By the 15th of February, these two plants were producing flower buds, and by February 20th, one had reached anthesis. Five plants of the same group and one much older but not receiving supplementary light were still completely vegetative. So far as is known, *C. frutescens* has shown little or no photoperiodic response. *Capsicum pubescens,* when grown in the field at Davis, flowers very sparingly, and under greenhouse conditions it is also reluctant to flower and set fruit. At Davis, this species appears to have little value horticulturally. In the field, growth is slow, flowering very late, and fruit set light. It apparently is highly resistant to tobacco mosaic, but this character is already available in *C. frutescens.* It has not been tested for resistance to other diseases. Because of its incompatibility with *C. frutescens,* noted below, it offers little promise for hybridization.

The basic chromosome number in the genus *Capsicum* is 12 (4). The diploid chromosome number of *C. pubescens* has been established as 24 (from leaf smears), which is the same as that known for most forms of *C. frutescens.* Smears from pollen mother cells of the two plants grown in the greenhouse at Davis in 1947 were made, and although the configurations present could not be established with certainty, univalents and chains were observed in the majority of cells examined. These two plants were both found to have less than 50 per cent of the pollen grains stainable.[2]

The two plants described above and five derived from them were crossed with several varieties of *Capsicum frutescens.* Over 100 crosses have been attempted using *C. frutescens* as the female parent. All but two flowers withered and dropped following pollination. The two remaining flowers set fruit with some seed, all but two of which were non-viable. The non-viable seeds which were examined were flat and without embryos. The two seeds which germinated proved to be selfs instead of hybrids. Approximately 50 crosses have been attempted using *C. pubescens* as the female parent, and these also were unsuccessful. Self pollination of the plants of both species used in making the crosses resulted in fruit set with the production of normal seed. The results of these experiments would tend to indicate that the two species are cross-sterile.

The data presented here, both morphological and cytogenetical, suggest that *Capsicum pubescens* might well be retained as a distinct species.

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[2]The sterility in these two plants seems to be an exception for the species as a whole. We have since secured plants with 90 per cent good pollen, and all of the plants cited in footnote 1 were found to have 80 to 100 per cent of the pollen grains stainable.

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Bacterial Spot Resistance in Peppers[1]

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The yield of Cayenne pepper in the Pee Dee area of South Carolina is often severely reduced by bacterial spot, *Xanthomonas vesicatoria,* (Doidge) Dowson. Higgins (1) and Weber (6) have reported that the disease is also destructive in Georgia and Florida, respectively. Horsfall and McDonnell (2) observed that there were wide differences in relative susceptibility to bacterial spot disease which appeared in epiphytotic form in a large varietal and strain collection of sweet peppers at the University of Connecticut and that resistance is probably inherited as a dominant. This disease is most prevalent during prolonged rainy seasons with high temperatures. All aerial parts of the plants are affected. As a result, complete defoliation has been observed on several varieties in the field. The disease, in addition to reducing the yield, reduces the market value of the pods since they lose their desirable red color. The lesions on the pods are also avenues for entrance of secondary organisms.

Field observations during the past 4 years have indicated that several varieties and selections of Cayenne pepper were somewhat resistant to bacterial spot. To ascertain more definitely the relative resistance of various lines, plants were artificially inoculated under greenhouse conditions during the spring of 1946.

Methods

Varieties of peppers studied were: Cayenne (six selections) Yatsuffa (two selections), Louisiana Sports, Santanka, Truhart Pimento. Inoculated and uninoculated plants were subjected, in a greenhouse, to (a) relatively high humidity, and (b) relatively low humidity. Approximately 100 per cent relative humidity was provided inside a chamber which was made of two layers of tobacco cloth and kept wet with a continuous fine water spray. Plants on open benches served as the low humidity group. The temperature was held above 27 degrees C during the day and 18 degrees C at night throughout the experiment, and other environmental conditions favorable for vigorous growth of the plants were maintained. The light intensity was slightly lower in the high humidity chamber than on the open benches, but this difference was not recorded.

Thirteen vigorous plants of each of the 11 varieties were grown under each of the two experimental conditions. Each plant was about 9 centimeters tall and was placed in a 15-centimeter clay pot filled with soil. The pots were plunged to the rims in sand on benches. Ten plants of each variety were inoculated, and three plants were left uninoculated as checks. The inoculated plants were sprayed with a water suspension of the bacterium, *Xanthomonas vesicatoria,* while the check

[1]Technical contribution No. 156 of the South Carolina Experiment Station. The author is indebted to Dr. B. B. Higgins, Plant Pathologist, Georgia Experiment Station, for supplying the culture of the bacterium, *Xanthomonas vesicatoria*, and to Dr. Alton E. Prince, formerly Assistant Professor of Botany, Clemson Agricultural College, for making the inoculations.

plants were sprayed with water only. After inoculation, all plants were arranged at random on the benches.

The method used was a modification of that devised by Knight and Clouston (3, 4) and Weindling (5) for testing resistance of cotton seedlings to *Xanthomonas malvacearum* (E.F. Sm) Dowson. A suspension containing approximately 1,000,000 bacteria per cubic centimeter was prepared from 7-day-old Petri dish (potato dextrose agar) cultures of the bacterium. The bacteria from one culture were sufficient for 12 liters of suspension which was enough to spray 30 pepper plants 12 weeks of age. Inoculations were made at noon on May 9, 1946 when the stomata on the underside of the leaves were open. The suspension was sprayed with considerable force against the underside of the leaves to simulate the effects of a downpour of rain. One application was adequate for severe infection of susceptible plants.

Observations

Inoculated plants held under high humidity conditions showed the first symptoms of infection 3 days after inoculation. By the fifth day differences in resistance of plants were evident. Final observations were taken 11 days after inoculation. Plants kept on the open greenhouse bench, where the humidity conditions were relatively low, showed a minimum of infections. Uninoculated plants remained free of infection throughout the experiment.

Results

The relative resistance to the disease of inoculated plants of several varieties and selections grown under high humidity conditions is indicated in Table I. The data (Table I) show that selections 4a–2–1, 4566, 4530P3 and 4512P2 are highly resistant. During the past 4 years these varieties have performed well in the pepper-growing area. Even before the test was initiated they were thought to have some

TABLE I—Resistance or Susceptibility of Plants of Pepper Varieties and Selections to *Xanthomonas vesicatoria* When Grown Under High Humidity Following Inoculation

Selection or Variety Number	Type of Pepper	Degree of Pungency	Resistance or Susceptibility to *Xanthomonas vesicatoria*
4a-2-1 4566*	Santanka Cayenne	Hot Very hot	*Highly resistant*—no infection or occasional lesions on youngest leaves.
4530P2 4512P2	Cayenne Cayenne	Very hot Very hot	*Moderately resistant*—young leaves spotted, lower or older leaves with few if any lesions; lesions dry and indistinct.
4537P1 4509P4	Cayenne Cayenne	Very hot Hot	*Moderately susceptible*—young leaves heavily infected, lower or older leaves spotted; lesions distinct, "water soaked," with little coalescence; severe defoliation.
Truhart Pimento Louisiana Sports 12b–1–1 9b–1–3 4556P6	Pimento Honka Yatsuffa Yatsuffa Cayenne	Sweet Very hot Hot Hot Mild	*Highly susceptible*—all leaves heavily infected with terminal leaves dead or dying; lesions large, "juicy," coalesced; severe defoliation.

*Hybrid obtained by crossing 4530P3 × 4537P1.

resistance to the organism. Selections 4537P1, 4509P4, 12B–1–1, 9b–1–3, and 4556P6, which are classified as moderately susceptible to very susceptible do not possess sufficient resistance to perform well under average seasonal conditions. The Truhart Pimento and Louisiana Sports, which were known to be susceptible to bacterial spot were included in the test as a means of comparison with other varieties and were found to be highly susceptible.

Figs. 1 and 2 are presented to show the resistance of one strain and the susceptibility of another to the disease.

It will be noted that the hot and very hot varieties vary considerably in their resistance to the disease. These observations as to the resist-

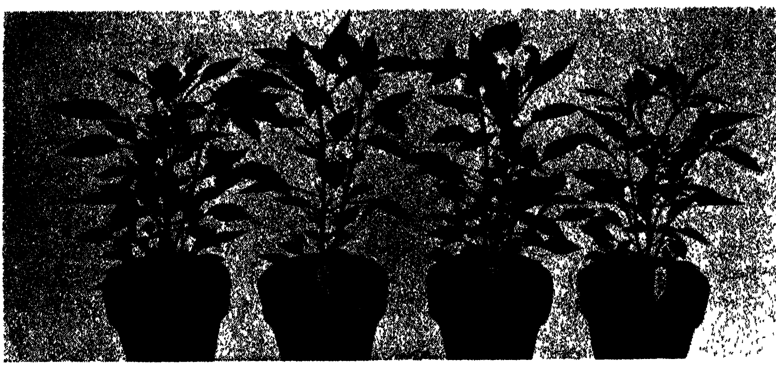

FIG. 1. A variety of hot pepper (4a–2–1) which is highly resistant to the bacterial spot disease (*Xanthomonas vesicatoria*). The two plants on the left were not inoculated; two on the right were artificially inoculated.

FIG. 2. A variety of hot pepper (9b–1–3) which is highly susceptible to the bacterial spot disease (*Xanthomonas visicatoria*). The two plants on the left were not inoculated; two on the right were inoculated artificially.

ance or susceptibility of the different varieties of pepper following artificial inoculation with bacterial spot in the greenhouse confirm observations of the behavior of these varieties and strains when subject to natural infection in the field. Strains 4a-2-1, 4566, 4530P3, and 4512P2 have been selected for further study because of their resistance to bacterial spot under conditions of natural and artificial infection. No. 4566, which was produced by crossing 4530P3 x 4537P1, possesses a greater degree of resistance to the bacterial spot organism than either of its parents.

In breeding for bacterial spot resistance, systematic progress can be facilitated by artificial inoculation. By providing conditions for testing the breeding stocks, plants may be selected with reasonable certainty of their resistance to the organism.

Description of Resistant Pepper Strains

Strain 4a-2-1:—The strain was obtained by selection from a Japanese variety (Santanka type) secured originally from the Pee Dee Experiment Station at Florence, South Carolina.

Characteristics:—The strain has a striking appearance and is very vigorous. It has a strong stalk of determinate growth, bears its fruit erect in umbels, and is very high in capsaicin content. The yield is good. It possesses marked resistance to root-knot nematodes.

Strain 4566:—The strain (a hybrid) was obtained by crossing 4530P2 with 4537P1, both parents were Cayenne pepper inbreds.

Characteristics:—It possesses much heterosis, has a striking appearance and has a strong and well developed stalk of indeterminate growth. The fruits are long, slender, pendant, and the capsaicin content is very high. The yield is excellent. It possesses marked resistance to root-knot nematodes.

Strain 4520P2:—The strain originated by selection from a single individual Cayenne pepper plant at Florence, South Carolina, in 1942.

Characteristics:—It is vigorous and has good appearance. It has a strong and well developed stalk of indeterminate growth which supports its fruits well above the ground level and stands up well during strong winds. The fruits are long, slender, pendant, easy to dry, and contain high amounts of capsaicin. The yield is good. It possesses marked resistance to root-knot nematodes.

Strain 4512P2:—The strain originated by selection from a single individual Cayenne pepper plant at Florence, South Carolina.

Characteristics:—It is not vigorous. The fruits are of medium size and contain moderate amounts of capsaicin. It is susceptible to root-knot nematodes.

Studies of the genetic factors involved in resistance to the disease will be initiated later.

Summary

Eleven varieties of peppers were artificially inoculated on May 9, 1946 with the bacterium, *Xanthomonas vesicatoria*, and grown under relatively low and high humidity conditions in the greenhouse. The

method of inoculation used was highly satisfactory in ascertaining the degree of resistance or susceptibility to the bacterial spot disease. For example, Truhard Pimento and Louisiana Sports Peppers, which are commercial varieties, were found to be highly susceptible to the bacterial spot disease. Cayenne varieties 4537P1 and 4509P4 are moderately susceptible. Santanka (4a–2–1) and Cayenne (4566) are highly resistant and Cayenne (4530P2) and (4512P2) are moderately resistant to the disease. A description of resistant lines is given.

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Climate and the Question of Time in Tomato Improvement[1] [2]

By W. A. Frazier, K. Kikuta, and J. W. Hendrix, *University of Hawaii, Agricultural Experiment Station, Honolulu, Hawaii*

In six years of essentially continuous year-round field planting of tomatoes in Hawaii, it has become obvious that the northern tropical climate of the islands has certain distinct advantages in a program designed to breed varieties resistant to several major diseases as well as for desirable vine and fruit characters. These advantages are largely the result of a favorable climate (1, 13). Near sea level the temperature ranges from 63 to 89 degrees F and at an elevation of 3,000 feet from 52 to 76 degrees throughout the year. The annual precipitation ranges from 10 inches to over 100 inches, depending upon location. The length of day ranges from 10.9 to 13.4 hours. The single adverse climatic factor results from the prolonged northeast trade winds, the bad effect of which can be greatly lessened by windbreaks. Such conditions promote rapid growth and development of the tomato (12). With early types, four generations can be grown per year. The original cross that produced Pearl Harbor was made May 21, 1941 (5). By December, 1947 it was in the 15th generation, field grown in each generation. *Lycopersicon hirsutum* fruits well during the winter, *L. peruvianum* at all seasons. A cross of *L. esculentum* — *L. peruvianum* required many months in the field before fruit set and seed production occurred (8). Since such interspecific hybrids grow over extended periods, the frost-free climate is advantageous in securing large quantities of seed.

Year-round observation of field-grown plants for resistance to the following diseases is possible in Hawaii: Fusarium wilt *(Fusarium oxysporum, F. lycopersici)* at low elevations; gray leaf spot *(Stemphylium solani)* at medium to low elevations (0 to 1,000 feet) (4); early blight *(Alternaria solani)* at medium to high elevations (1,000 to 2,500 feet); late blight *(Phytophthora infestans)*, especially at high elevations; Septoria leaf spot *(Septoria lycopersici)*, especially at medium to high elevations; bacterial wilt *(Phytomonas solanacearum)* destructive in some areas; spotted wilt virus is greatly favored by the maintenance of an *Emilia sonchifolia* nursery in the field (7); root knot *(Heterodera marioni)* at low elevations (11); tobacco mosaic virus resistance can be studied best with large numbers of mature plants (6).

Regions such as Hawaii may be pictured as vast outdoor greenhouses that could be utilized for initial observation of field-grown plants and for rapid turnover of generations. Final proof of value elsewhere, of course, would come only after tests were conducted in each region. This would apply not only to the plant's reaction to varied soils and climates, but its reaction to attack by possible varying strains

[1]Published by permission of the Director of the Hawaii Agricultural Experiment Station as Technical Paper No. 162.

[2]This is a summary of a more complete paper presented to the Society.

of a given disease organism (9, 10). Indeed, it is fully recognized that many questions are involved in rapidity of development of complex plant breeding programs (2, 3). It would perhaps be well for tomato breeders everywhere to give more thought to the unique advantages which surround their work, and to formulate, ultimately, national or international coordinated plans to effect more rapid and lasting improvement of the plant.

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Culture of Solanum Nigrum Embryos[1]

By CHESLEY B. HALL, *Purdue University, Lafayette, Ind.*

AN attempt was made by the author to cross *Lycopersicon esculentum* with *Solanum nigrum*. Anticipating that embryos formed from this cross might abort before reaching maturity, a program of culturing embryos in vitro was initiated. As tomato embryos had already been successfully grown by Smith (3), it was decided to concentrate on the culture of *S. nigrum* embryos.

All embryos used were excised in sterile distilled water. A dissecting microscope was used to aid in the excision of the embryos. Aseptic technique was used throughout.

The data were ranked by giving an embryo showing no growth a score of 0, an embryo showing any growth of root or shoot, a score of 1, and an embryo which developed roots and shoot a score of 2. The data were then transformed as shown by Snedecor (4), by adding 0.5 to each score and taking the square root of the resultant number. Thus, with these transformed data 0.71 represents no growth, 1.22 represents some growth and 1.58 represents growth of root and shoot. The square roots were used for running the analyses. The results are given on the basis of these square roots. The number of embryos per treatment ranged between 5 and 25.

EFFECT OF TYPE OF MEDIUM

The first objective was to find a nutrient medium suitable for the growth of immature *Solanum nigrum embryos*. The formulae of Smith (3), Randolph and Cox (1), Tukey (5) and Robbins (2), all with 2 per cent sucrose as the carbohydrate were tried. Of the four media, Tukey's gave by far the best growth. It was, therefore, used as the basic medium for all succeeding experiments with the exception of the one involving temperature and endosperm.

EFFECT OF TEMPERATURE AND ENDOSPERM

Mature *Solanum nigrum* embryos were used in this experiment. One-half the embryos were excised without endosperm and one-half were excised enclosed in the endosperm for each of two temperatures, 25 degrees C and 32 degrees C. The embryos were placed on sterile, moist filter paper in petri dishes in diffuse light at their respective temperatures for 7 days. No nutrient medium was used in this experiment.

A highly significant difference was found in favor of the higher temperature. There was no significant difference between the embryos enclosed in endosperm and those without endosperm. These results are given in Table I.

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TABLE I—EFFECT OF TEMPERATURE AND ENDOSPERM UPON THE GROWTH OF MATURE *Solanum Nigrum* EMBRYOS

Temperature (Degrees C)	Endosperm		Average Growth Index
	Present	Not Present	
25	1.00	1.19	1.10
32	1.54	1.30	1.42
Average growth index	1.27	1.24	

Difference for significance of main effect averages
At 5 per cent level .. 0.18
At 1 per cent level ... 0.25

RELATION OF CARBOHYDRATE SOURCE AND CONCENTRATION

To check the effect of the carbohydrate source and concentration, sucrose and two samples of d-glucose from different sources at concentrations of 0.5 per cent, 1.0 per cent and 2.0 per cent were used with 16-day embryos about 1.75 mm long.

The results indicated a highly significant difference in favor of sucrose over either sample of d-glucose. There was no significant difference between concentrations, however. Table II shows the least significant difference for these data.

TABLE II—COMPARISON OF THE EFFECT OF SUCROSE, AND TWO SAMPLES OF D-GLUCOSE ON THE GROWTH OF 16-DAY *Solanum Nigrum* EMBRYOS

Carbohydrate	Concentration (Per Cent)			Average Growth Index
	0.5	1.0	2.0	
Sucrose	1.01	0.90	1.08	1.00
D-Glucose I	0.96	0.75	0.82	0.85
D-Glucose II	0.88	0.86	0.78	0.84
Average growth index	0.95	0.84	0.89	

Difference for significance of main effects averages
At 1 per cent level—0.14.

EFFECT OF COCONUT MILK

Van Overbeek, Conklin and Blakeslee (6) reported that coconut milk in the medium was necessary for the growth of *Datura stramonium* embryos under 0.5 mm. Smith (3) reported that coconut milk was not beneficial to the growth of embryos of a tomato species hybrid.

Raw coconut milk, sterilized by using a Seitz filter, was tried with *Solanum nigrum* embryos with no beneficial effects on the growth of either 15-day, 13-day or 12-day old embryos. In fact, 15-day old embryos gave significantly better growth on Tukey's medium with 1 per cent sucrose than on the same medium containing coconut milk.

EFFECT OF AGAR CONCENTRATION

Up to this point, the agar concentration used was from 0.66 per cent to 1.0 per cent depending upon the medium. To test the effect of agar on embryo growth, five concentrations of agar, *viz,* 0.25 per cent, 0.50 per cent, 0.66 per cent, 1.0 per cent and 2.0 per cent were used with 16-day old embryos.

The results of the experiment showed a highly significant difference between agar concentrations. A concentration of 0.25 per cent gave the best growth while a 2.0 per cent concentration gave no growth. Concentrations of 0.25 per cent to 1.0 per cent gave erratic results but were about equally good. Higher concentrations would appear to be detrimental. Table III gives the significant difference between concentrations.

TABLE III—EFFECT OF AGAR CONCENTRATION ON THE GROWTH OF 16-DAY *Solanum Nigrum* EMBRYOS

	Agar Concentration (Per Cent)				
	0.25	0.50	0.66	1.0	2.0
Average growth index	1.02	0.91	0.85	0.91	0.71

*0.71 represents no growth.
Difference for significance
At 5 per cent level—0.16
At 1 per cent level—0.22

EFFECT OF pH

The pH value of Tukey's medium is about 5.5 and had not been changed in any of the previous experiments. A number of pH values were used to determine which was the best for the growth of *Solanum nigrum* embryos. The values at the beginning of the culture period were as follows: 4.5, 5.0, 5.5, 6.0, 6.5, and 7.0. Sixteen-day old embryos were used.

The data were transformed in the same manner as in the other experiments, but in this case a correlation was run between the amount of growth and the pH of the medium. The value of the coefficient of determination, r^2, was 0.034 which was significant at the 5 per cent level with 124 degrees of freedom.

As r was a positive value, the results indicated that growth increased as the pH of the medium was raised. Table IV gives the average growth index for each pH value.

TABLE IV—EFFECT OF pH ON THE GROWTH OF 16-DAY *Solanum Nigrum* EMBRYOS

	pH of Medium					
	4.5	5.0	5.5	6.0	6.5	7.0
Average growth index	0.90	0.79	0.84	0.91	0.94	1.06

CONCLUSIONS

1. Tukey's medium was better for the growth of *Solanum nigrum* embryos than the media of Smith, Randolph and Cox, and Robbins.
2. Growth of mature *Solanum nigrum* embryos was significantly better at 32 degrees C than at 25 degrees C.
3. The presence of endosperm was not advantageous in the initial growth of mature *Solanum nigrum* embryos.

4. Sucrose was significantly better than d-glucose for the growth of 16-day *Solanum nigrum* embryos.

5. An agar concentration of 2 per cent was detrimental to the growth of 16-day *Solanum nigrum* embryos whereas concentration of 0.25 per cent to 1.0 per cent gave about equally good growth.

6. A positive correlation existed between pH and growth showing an increase in the growth of 16-day old *Solanum nigrum* embryos with an increase in pH from 4.5 to 7.0.

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Nutrient-Element Balance and Time of Anthesis in Tomato Flowers[1]

By Victor N. Lambeth, *University of Missouri, Columbia, Mo.*

The concept of nutrient-element balance in plant nutrition has in the past few years received added impetus. The increasing demand for more information concerning nutrient-element relationships in both greenhouse soil and in the field has apparently stimulated work in this direction. With growth of the concept has come considerable confusion as to the meaning and application of the phrase. As used in this paper, nutrient-element balance refers to the proportions of the essential macro nutrient-elements added to the substrate.

Considering a reduced rate of growth as the first and often the only observed symptom of soil nutrient-element deficiency, an experiment was conducted in the greenhouse in the fall of 1946 to determine what constitutes a balanced nutrient supply of nitrogen, phosphorus, and potassium for the tomato plant, and to what extent the time of anthesis of the plant can be influenced by the balance of supply of these elements.

Methods

Tomato plants of the Master Marglobe variety were grown from seed in 2-gallon glazed jars in a prepared substrate consisting of Putnam Clay subsoil, vermiculite filler, and added plant nutrients. Use of the colloidal clay technique (1) permitted a wide range in the levels of nitrogen, phosphorus, and potassium with constant base saturation of the clay, a constant pH (5.2), and a constant low osmotic pressure in the soil solution. The use of vermiculite in the medium provided a wider latitude in the water relations of the plants than is possible when white sand is used as the filler (2).

The levels of nitrogen and phosphorus were 45, 90, and 180 milliequivalents (m e) per jar; those of potassium were 22.5, 45, and 90 m e. Calcium was held constant throughout the series at 100 m e. The magnesium and sulfur levels were each constant at 20 m e per jar. All possible combinations of the above elements resulted in 27 treatments, and with six replications per treatment, a total of 162 jars.

The date of anthesis of each flower of the first cluster was recorded. Using the earliest flowering date of the entire series as a base, the number of days delay in anthesis from this date was determined for each flower of the first cluster. An average of these values for the first three flowers of the first cluster was then calculated. This gave a relative comparison of the difference in flowering date for the various treatments.

Results and Discussion

The results show there were several combinations about equally favorable for early anthesis. These combinations expressed in m e of nitrogen, phosphorus, and potassium respectively are 45–90–22.5,

[1]Contribution from the Department of Horticulture, Missouri Agricultural Experiment Station Journal Series No. 1086.

45-90-45, 45-180-22.5, 45-180-45, 90-180-45, and 180-180-90. These treatments were in general the same as those favoring maximum total growth. The time of anthesis was particularly correlated with growth in those treatments showing the highest degree of unbalance (treatment 3, Table I, for example) where marked delay in anthesis occurred on those plants which were definitely "stunted" in growth. This would indicate that the time of anthesis is related to the physiological age of the plant.

TABLE I—CORRELATION OF N-P-K WITH GROWTH AND TIME TO ANTHESIS

Treatment	N* M E	P* M E	K* M E	Average Height of Plants (Cms) 48 Days	Averaged Delay in Time to Anthesis** (Days)
1	180	180	90.0	31.5	2
2	180	90	90.0	28.9	6
3	180	45	90.0	14.9	17
4	180	180	45.0	30.1	4
5	180	90	45.0	26.9	9
6	180	45	45.0	21.6	10
7	180	180	22.5	32.5	6
8	180	90	22.5	29.5	5
9	180	45	22.5	22.2	11
10	90	180	90.0	29.8	5
11	90	90	90.0	28 4	6
12	90	45	90.0	18.7	13
13	90	180	45.0	36.2	2
14	90	90	45.0	37.2	10
15	90	45	45.0	30 6	10
16	90	180	22.5	33.4	4
17	90	90	22.5	35.3	4
18	90	45	22.5	31.2	8
19	45	180	90.0	28.9	5
20	45	90	90.0	29.8	5
21	45	45	90.0	28.1	7
22	45	180	45.0	36.2	2
23	45	90	45.0	35.6	2
24	45	45	45.0	30.7	4
25	45	180	22.5	34.2	2
26	45	90	22.5	34.9	2
27	45	45	22.5	30.8	5

*M E of N, P, K added to each jar in the various treatments.

**The averaged delay in time to anthesis is for the first three flowers of the first cluster and is based on the earliest flowering date of the series.

Other nutrient elements added at a constant level were Ca at 100 M E, Mg at 20 M E, and SO_4 at 20 M E.

It is evident that anthesis occurred significantly later at the higher nitrogen levels as compared to the lowest level. Within any nitrogen level, however, an increase in the phosphorus supply acted to hasten anthesis. This tendency was more marked at the low nitrogen supply. Also with phosphorus at 45 m e level, the delaying effect of a high nitrogen supply on the time of anthesis was magnified at the higher potassium level.

At the 180 m e nitrogen level with potassium high (90 m e), an increase in the phosphorus level from 45 to 90 m e decreased the average time for anthesis by 11 days. Further increase in the phosphorus supply to 180 m e reduced this time a total of 15 days. However, variations in the phosphorus supply at this level of nitrogen with potassium at a low level were not so effective in inducing early anthesis.

At the 90 m e nitrogen level, anthesis occurred earlier with a medium potassium and a high phosphorus supply. As at the high nitrogen

level, anthesis occurred later on plants of those treatments with a low phosphorus and a high potassium supply in the substrate. An increase in phosphorus supply from 45 to 90 m e had no effect on time of anthesis of those plants at the medium levels of nitrogen and potassium. Further increase of phosphorus to 180 m e, however, hastened the average time of flowering by 8 days.

The time required for anthesis at the 45 m e nitrogen level was as a whole significantly less than at the other two levels. Variations in time of flowering of 2 or 3 days occurred with variations in the phosphorus and potassium supply within this nitrogen series. The highest intensity of balance of the entire series as reflected by early flowering occurred in this nitrogen level at the N45–P90–K22.5 combination.

That the nitrogen supply alone is not responsible for the wide variation in time of anthesis is shown by comparing the average time of anthesis between the three nitrogen levels with the variation within any nitrogen level. In many cases it was found that the variation within a given level exceeded that between the nitrogen levels.

Summary

A difference of as much as 15 days occurred in the averaged time of anthesis by varying the proportions of nitrogen, phosphorus, and potassium on the clay at base saturation level. This was shown to reflect a favorable intensity of balance of these nutrients in the substrate rather than a direct effect of a supply of any one element.

Anthesis was shown to occur later at the higher nitrogen treatments. This was not due to the plants being excessively "vegetative", which is sometimes correlated with delayed anthesis, since from a growth standpoint these plants were not as large as plants showing earlier anthesis.

The highest intensity of balance as determined by early flowering occurred at the N45–P90–K22.5 m e combination. In most instances it was found that the treatments favoring the most total growth were also the ones most conducive to early flowering.

A high N/P ratio resulted in delayed anthesis and a high P/N ratio hastened flowering. The most favorable ratios of N to P for early anthesis were 1 : 1 and 1 : 2 on the m e basis. In any case, however, it was true that the tendency of any element to hasten or delay the time of anthesis was effective only with a favorable balance of supply of the other elements considered.

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Effect of Plant Training and Number of Pollinations Per Cluster on Production of F_1 Hybrid Tomato Seed in the Greenhouse[1]

By Emil A. Wolf and E. C. Stair, *Purdue University, Lafayette, Ind.*

Observing Spartan Hybrid Tomato, an F_1 hybrid between varieties Michigan State Forcing and Cooper Special (1) for two seasons, the junior author concluded that this hybrid could be used profitably by Indiana greenhouse growers. Since seed of this hybrid was not available through commercial channels, a small amount was then produced in the greenhouse in 1945 for introductory purposes. Because a high percentage of fruit set, consistent with that reported by other workers (2, 3) was obtained in this work, and because it is unnecessary to cover flowers in a screened greenhouse to prevent accidental cross pollination, seed was similarly produced in 1946.

It was hoped that growers, finding Spartan Hybrid to be superior to the varieties they commonly grew, would be encouraged to produce their own seed. Accordingly, records were kept in 1946 to obtain information on the amount of space and pollination time required to produce an ounce of seed in the greenhouse.

During the 1946 work, the question arose whether pruning the Michigan State Forcing plants to a single stem and pollinating all flowers of a cluster was the most efficient method of utilizing labor and greenhouse space. An apparent reduction in set of the last flowers on large clusters was observed which indicated that limiting the number of pollinations per cluster to a certain maximum number might yield practically the same amount of seed with fewer pollinations. Barrons and Lucas (2) report a marked decrease in percentage of fruit set in the field after pollinating three flowers per cluster. Oba, Riner, and Scott (3) have later reported that there was no significant difference in set in the greenhouse between pollinating from two to eight flowers per cluster. Hence, a factorial experiment of split-plot design was conducted in 1947 to study the combined effects on total seed production of a plant resulting from (a) pruning plants to a double stem instead of a single stem, (b) pollinating flowers of the first cluster or omitting them, and (c) limiting the number of flowers pollinated in each cluster on the plant to 3, 4, or 5 as opposed to pollinating all flowers.

1946 Production of Hybrid Tomato Seed

Thirty-two Michigan State Forcing plants, spaced 2 feet by 2½ feet in ground beds and pruned to a single stem, were used as seed parents. A row of Cooper Special plants, trained to a double stem, was between the first and second and another between the third and fourth rows of Michigan State Forcing. The basic techniques of emasculation and pollination of flowers were the same as those employed by Barrons and Lucas (2), except for the collection of pollen,

[1]Journal Paper No. 331, Purdue University Agricultural Experiment Station.

which was collected and transferred to emasculated flowers on a glass slide. Pollinations were made over a 2-month period from April 16 to June 15 and all flowers pollinated were tagged. Attempt was made to pollinate all flowers and any which passed the proper stage for emasculation were removed. The Michigan State Forcing plants were pruned as they were being examined for flowers and this pruning was included in the time records.

Three hundred ninety-one grams of hybrid seed were obtained by 79 hours of pollination-pruning work. This seed was produced by 1339 mature fruits. The average weight of eight samples of 1,000 seeds each was 4.09 grams with a standard deviation of .18 grams. Each fruit, therefore, produced about 70 seeds. Although no record was kept of the total number of pollinations attempted, fruit set was estimated at 75 to 80 per cent.

Each seed parent plant produced slightly more than 12 grams of seed (approximately 3000 seeds). Seventeen and four-tenths square feet of greenhouse space, including that occupied by the pollen parents, and 5¾ hours of pollination-pruning time were required to produce 1 ounce of seed (approximately 7,000 seeds).

In order to correct the combined pollination pruning time recorded in this study to pollination time records were kept in the 1947 experiment of time spent and number of flowers pollinated during the period of May 16 to June 2. Nine hundred seventy-six pollinations were made in 16½ hours, an average of 59 pollinations per hour. This indicates that with 75 per cent fruit set only 2¼ hours actual pollination time was required to produce 1 ounce of seed.

Cost of Producing Hybrid Tomato Seed in the Greenhouse

Cost of hybrid seed to the grower producing his own seed in the greenhouse includes the value of the tomatoes which could have been produced and marketed from the same space as well as the value of the extra time spent in making pollinations and extracting seed. It required about 3 hours to extract 1 ounce of seed by hand in the 1946 study. Assuming an average yield of 10 pounds of marketable fruit per plant and a selling price of 30 cents per pound, a regular crop of tomatoes will return 60-cents per square foot of space. Thus, on the basis of the 1946 study, and labor at 70 cents per hour, it would cost the grower approximately $14.00 to produce 1 ounce of hybrid seed in his greenhouse. Results obtained in the 1947 experiment indicates that by pruning plants to a double stem this cost may be reduced to about $10.00. A grower, therefore, can produce his own Spartan Hybrid tomato seed on a few Michigan State Forcing plants in a regular spring tomato crop at much less cost than current commercial prices. Such a procedure would be much more convenient for the grower than a separate small scale field operation and thereby insure his supply of hybrid tomato seed.

Effect of Plant Training and Number of Pollinations

Procedure:—Nine rows of plants were divided into three blocks, each consisting of two rows of Michigan State Forcing with a row of

Cooper Special between. Planting distances were the same as in the preceding year. In each block, one row of Michigan State Forcing plants was trained to a double stem and one row to a single stem. Each block of plants was then subdivided into two plots, each containing four seed parent plants pruned to a single stem and four pruned to a double stem with four pollen parent plants between. On one plot, flowers were pollinated on the first cluster; on the other, flowers of the first cluster were removed. The four limits established for number of pollinations per cluster were assigned at random to the four plants pruned to a single stem and to each of the four double stemmed plants. On one plant all flowers were pollinated; on the other three plants, pollinations were limited to maximums of three, four and five per cluster. This gave three replications for each of the 16 different combinations of individual plant treatments. Pollinations were begun on April 25 and discontinued June 16. The data were subjected to Analysis of Variance (4).

Results:—There was no significant difference in set whether plants were pruned to a single or double stem or whether the first cluster was pollinated. A highly significant increase in set, however, was obtained by decreasing the number of flowers pollinated per cluster. The average percentage of fruit set obtained from the various treatments is given in Table I. From 1 to 16 flowers were pollinated per cluster on the 12 plants having all flowers pollinated. A study of 89

TABLE I—PERCENTAGE OF FRUIT SET OBTAINED FROM HAND POLLINATIONS IN THE 1947 GREENHOUSE HYBRID TOMATO SEED PRODUCTION EXPERIMENT (SIXTEEN TREATMENTS — THREE PLANTS FOR EACH TREATMENT)

Plant Pruning and Treatment of First Cluster	Maximum Number of Pollinations Per Cluster on a Plant Percentage of Fruit Set (3 Plant Average)			
	3	4	5	No Limit
Single stem—1st cluster pollinated	95.0	88.0	89.0	77.0
Single stem—1st cluster omitted	98.0	94.0	81.0	71.0
Double stem—1st cluster pollinated	83.0	85.0	84.0	80.0
Double stem—1st cluster omitted	87.0	86.0	77.0	85.0
Per cent of fruit set* (12 plant average)	90.8	88.3	82.8	79.8

*Least significant difference for odds of 19:1 is 6.5 per cent.

TABLE II—AVERAGE WEIGHT IN GRAMS OF HYBRID TOMATO SEED OBTAINED PER PLANT IN THE 1947 GREENHOUSE PRODUCTION EXPERIMENT (SIXTEEN TREATMENTS — THREE PLANTS PER TREATMENT)

Plant Pruning and Treatment of First Cluster	Maximum Number of Pollinations Per Cluster on a Plant Grams of Seed Produced Per Plant (3 Plant Average)				Amount of Seed Produced Per Plant in Grams (12 Plant Average)
	3	4	5	No Limit	
Single stem—1st cluster pollinated	3.24	4.91	6.44	8.09	5.67
Single stem—1st cluster omitted	3.07	1.91	4.79	5.11	3.72
Double stem—1st cluster pollinated	6.19	7.59	10.05	9.11	8.24
Double stem—1st cluster omitted	4.52	6.73	6.52	9.74	6.88
Grams of seed produced per plant (12 plant average)*	4.26	5.29	6.95	8.01	

*Least significant difference for odds of 19:1 is 1.47 grams.

fully developed clusters on these 12 plants revealed that 65 per cent of the clusters received more than five pollinations each, and 36 per cent received eight or more. No significant difference was found in the percentage of set on the 85 clusters receiving from 2 to 11 pollinations each when the data were analyzed statistically. There were 548 pollinations on these 85 clusters.

The average production of seed per plant from the various treatments is given in Table II. Analysis of the data shows a highly significant difference in the amounts of seed obtained from (a) the different numbers of pollinations, (b) inclusion and omission of the first cluster, and (c) pruning plants to a single and a double stem.

Three samples of 100 seeds each were drawn from the bulked, well mixed seed of each plant and weighed. There was found to be no satistically significant difference in seed weights, however, there was an indication that seed produced by the plants pruned to a double stem might be smaller.

Discussion

Seed production was greatest in the 1947 experiment from plants pruned to a double stem and on which all flowers were pollinated. Therefore, if maximum seed production from a minimum of greenhouse space is the primary consideration, the grower should pollinate all flowers and prune seed parent plants to a double stem or use a close spacing of single stemmed plants. This would not be recommended, however, if the grower is troubled by leaf mold, *Cladisporium fulvum* (Cke.)

It does not appear advisable for the grower who has limited time to attempt pollination of all flowers. In this experiment, limiting the number to five flowers per cluster resulted in a slight increase in set and a slight decrease in the total amount of seed obtained from a plant. Neither the increase in set nor the decrease in seed, however, is statisically significant when the 12 plant means of the two treatments are compared with their least significant differences. This appears to be contradictory in that approximately 25 per cent more pollinations were made when all flowers were pollinated. A corresponding increase should have been produced by the increased number of pollinations, yet the actual increase obtained was only about 15 per cent. Evidently fewer seeds were obtained from pollinations made on the later appearing flowers of the larger clusters.

Under the conditions of this experiment, the limit of five flowers per cluster appears to be too low for most efficient use of greenhouse space since 65 per cent of the clusters, on plants where all flowers were pollinated, received more than five pollinations each. Neither does pollination of all flowers appear to be most efficient in utilization of time and space in view of (a) the lower set obtained when all flowers are pollinated, (b) the relatively large amount of time spent in locating the last flowers which appear in the clusters, and (c) the reduced amounts of seed obtained from pollination of these last flowers.

Summary

In 1946, Michigan State Forcing plants, pruned to a single stem, produced approximately 3000 seeds per plant when attempt was made to cross-pollinate all flowers. Seventeen and four-tenths square feet of greenhouse space, including that used by the pollen parents, and 5¾ hours of pollination-pruning time were required to produce 1 ounce of seed (approximately 7000 seeds). A study of pollination time in 1947 indicates that 2¼ hours pollination time alone was required to produce 1 ounce of seed.

A factorial experiment of split-plot design was used in 1947 to study the combined effects on total hybrid seed production of Michigan State Forcing plants from (a) pruning plants to a double stem instead of a single stem, (b) pollinating flowers of the first cluster as opposed to omitting them, and (c) limiting the number of pollinations in each cluster of the plant to 3, 4, or 5 as opposed to pollinating all flowers. It was found that:

1. From 64 to 100 per cent fruit set was obtained on plants receiving the various treaments.

2. There was no significant difference in the per cent of set whether plants were pruned to a single or double stem or whether the first cluster was included or omitted.

3. There was a significant increase in percentage of set on a plant as the maximum number of pollinations per cluster was decreased. An increase of set on plants limited to five pollinations per cluster over plants having all flowers pollinated is indicated but is not significant in this experiment. This increase became significant when only four flowers were pollinated per cluster.

4. Production of seed was approximately 60 per cent greater on plants pruned to a double stem than on plants pruned to a single stem.

5. A significant increase in the amount of seed was obtained when the first cluster was included.

6. When the number of pollinations is limited to pollination of five flowers per cluster, a reduction in the total amount of seed produced on a plant is indicated, but is not significant in this experiment. This decrease was significant when only four flowers were pollinated per cluster.

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The Description and Inheritance of a Functionally Sterile Flower Mutant in Tomato and Its Probable Value in Hybrid Tomato Seed Production[1]

By R. E. Larson and Sherman Paur, *The Pennsylvania Agricultural Experiment Station, State College, Penn.*

The use of male sterile lines of tomatoes to facilitate production of F_1 hybrid seed has been frequently suggested (1, 2, 4, 6, 12, 14). They are still not in common usage, however, probably because the male sterile lines have not indicated superior combining ability, the maintenance of such lines even though the segregation is 1 : 1 in a backcross population for a simple recessive is laborious, and no great reduction in time required to produce a given quantity of crossed seed has thus far been evidenced.

It is logical to expect, however, that a good combining male sterile line having a style of sufficient length to expose the stigmatic surface and lending itself to simple propagation, would be of considerable value to the seed industry. The cost of production would be greatly reduced and the danger of obtaining selfed rather than crossed seed, due to carelessness of inexperienced workers, would be nil. The acquisition of such a line has been of paramount interest to a number of tomato breeders.

Sterile plants are most easily identified late in the growing season because of their abundance of vegetative growth and lack of leaf diseases. In August, 1945, a sterile plant was obtained in a planting of John Baer tomatoes.[2] Cuttings were taken and rooted in the greenhouse. Subsequent studies revealed that this mutant would set an abundance of seed when artificially selfed or crossed, but set practically no seed naturally.

Morphology

Fig. 1 shows the normal and mutant forms of flowers. The tomato blossom is hypogynous and actinomorphic and is normally polypetalous. In the mutant form the flowers are essentially the same except that the petals have either a greater lateral growth or are in some instances gamopetalous showing coalescence of the corolla nearly to their extremity. The greater lateral growth of the petals causes an overlapping and curling with the adjacent petals. In cross section this resembles the hooked sections of a tin can compressed to form the side seam (Fig. 2). The petals in either case, therefore, are unable to diverge. The corolla is normally joined by hair development near the segment tips as are the anthers (Rick, 15). "At anthesis the weak binding effected by the multicellular hairs is broken by tension of the expanding corolla resulting in a separation of the petals." A polysepalous calyx is produced in both the normal and mutant forms.

[1]Authorized for publication on March 16, 1948 as paper No. 1435 in the Journal Series of The Pennsylvania Agricultural Experiment Station.

[2]*Science 107: No. 2785, p. 506.* This plant occurred as a mutant in the experimental plots of, and has been propagated and maintained by, the Pennsylvania Agricultural Experiment Station.

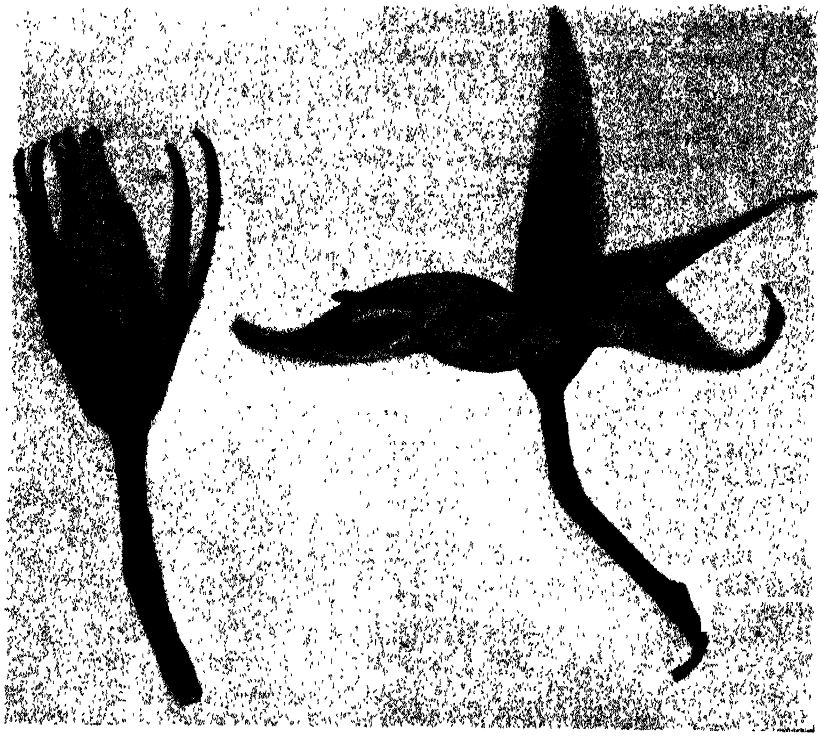

FIG. 1. The mutant and normal forms of tomato flowers at the same stage of maturity.

The interlocking of the petals of the mutant form and the uneven constrictive force they apply to the exterior of the anther cone results in a convoluted petalous condition giving the appearance of extremely irregular growth. The connate or pseudo-connate form of the petals results in considerable constriction of the anthers and tends to hold them in exceedingly close contact with the pistil, particularly at the apex. In view of this condition it was thought that the smallness of the opening between the anthers and the style might prevent pollen escape. Slicing away the tips of the corolla and anthers, without cutting into the microsporangium, failed to indicate, however, any greater escape of pollen.

It was also supposed that the constrictive force might tend to prevent rupture of the stromium; although dehiscence is introrse, however, it is nevertheless almost at right angles to the style. Since the space between the separate anthers appears to be ample, this supposition could not be substantiated.

In the mutant as well as the normal form the conjunctive tissue between the lobes of the microsporangia was apparently dissolved (Fig. 3). In cross section views of the mature anther of the mutant form, however, the epidermal cells making up the stromium appeared

FIG. 2. Cross section view of anther tube and petals of the mutant tomato flower — ×50; *p*. petals, *c*. conjunctive tissue, and *m*. microsporangia.

to be intact (Fig. 3), excepting where breakage had occurred through difficulties of sectioning. It appears that the unusual tenacity of the stromial cells might cause the functional sterility. If this is the case it should be possible to obtain a normal flowered functional sterile unless there is an extremely close linkage between the morphological condition of the flower and the strong walled stromium.

Not a single normal flowered sterile plant was obtained from 1434 F_2 progenies. All F_2 plants having the mutant flower form, however, were found to be functionally sterile.

The fundamental condition underlying this form of sterility has not been ascertained. Morphological studies are being continued in hopes of clarification.

INHERITANCE

Progenies resulting from selfing of the original abnormal flower type were found to breed true for this characteristic.

Crosses were made involving the varieties Bounty and Strain No. 178 with the mutant form. Both varieties are uniform ripening and produce normal flowers. Bounty is a dwarf determinate, while No. 178 is a determinate of the Pritchard type. The mutant resembled the original John Baer in all respects excepting flower type; that is, non-uniform ripening fruit and indeterminate plant habit.

FIG. 3. Cross section view of mature anthers in the tomato mutant showing disjunction of connective tissue between the microsporangia and the intact epidermal cells of the stromium — ×135. *p.* petal, *c.* conjunctive tissue remains, *m.* microsporangia, and *s.* stromium.

The F_1 plants obtained from the afore-mentioned crosses were uniformly indeterminate, non-uniform ripening, and normal flowered. Selfed seed was obtained from these F_1 lines and seeds from several backcrosses to the abnormal flower type also were secured.

In 1947, the F_2 and backcross progenies, shown in Table I, were grown in the field. The observed segregation in the F_2 for the normal and mutant flower forms is compared by means of the X^2 test for goodness of fit to a 3:1 ratio (Table II), the expected segregation of a simple recessive in F_2 population; and to a 1:1 ratio similarly expected in the backcross progenies (Table III). A fair fit is noted in F_2 population 1–S and a rather poor fit in 2–S. Chi square values for backcross populations 4–S, 5–S, and 6–S indicate close

TABLE I—F_2 AND BACKCROSS POPULATIONS STUDIED

Population Number	Generation	Parental Lines
1-S	F_2	J. B. Sterile × Bounty
2-S	F_2	J. B. Sterile × 178
4-S	BC 1	J. B. Sterile × (J. B. Sterile × Bounty)
5-S	BC 1	(J. B. Sterile × No. 178) × J. B. Sterile
6-S	BC 1	J. B. Sterile × (J. B. Sterile × No. 178)

TABLE II—SEGREGATION IN THE F_2 GENERATION FOR NORMAL AND MUTANT FLOWER TYPES

Population No.	Normal		Mutant		P From X^2 For 3:1 Ratio
	Obs.	Calc.	Obs.	Calc.	
1-S	360	348.75	105	116.25	0.20–0.30
2-S	749	726.75	220	242.25	0.05–0.10
Total	—	—	—	—	0.10–0.20
Deviation	1,109	1075.50	325	358.50	0.02–0.05
Heterogeneity	—	—	—	—	0.95–0.98

TABLE III—SEGREGATION IN BACKCROSS GENERATION FOR NORMAL AND MUTANT FLOWER TYPES

Population No.	Normal		Mutant		P From X^2 For 1:1 Ratio
	Obs.	Calc.	Obs	Calc.	
4-S	244	256.0	268	256.0	0.20–0.30
5-S	11	11.0	11	11 0	—
6-S	38	39.5	41	39.5	0.70–0.80
Total	—	—	—	—	0.70–0.80
Deviation	293	306.5	320	306.5	0.20–0.30
Heterogeneity	—	—	—	—	0.80 0.90

agreements to a 1 : 1 segregation. It is evident that the mutant flower type is inherited as a simple recessive to which the gene symbol *ps* has been assigned.

Self topping plant habit is inherited as a simple recessive (8, 9), as also is uniform habit of ripening (10). The F_2 progenies also segregating for these characteristics provided additional confirmation of their mode of inheritance. All abnormal flower segregants were artificially self-pollinated, so that immature color of fruit could be recorded.

In an analysis of the combined inheritance of immature fruit color and flower type in the F_2 populations, relatively good fits to a 9 : 3 : 3 : 1 ratio were obtained (Table IV), indicating independent segregation.

Although a good fit to a 9 : 3 : 3 : 1 was obtained in F_2 population

TABLE IV—SEGREGATION IN F_2 FOR NON-UNIFORM VERSUS UNIFORM RIPENING OF FRUIT (Uu) AND NORMAL VERSUS ABNORMAL FLOWER TYPE (Ps ps)

Population No.	F_2 Plants in Class				P For Goodness of Fit to 9:3:3:1 Ratio
	UU		uu		
	Ps Ps	ps ps	Ps Ps	ps ps	
1-S	279	73	81	32	0.20–0.30
2-S	564	153	185	63	0.10–0.20

1–S for the inheritance of flower type and plant habit, in F_2 population 2–S a P of 0.01–0.02 suggested relatively poor agreement (Table V). To test whether this discrepancy might be due to linkage a component X^2 analysis was made (Table VI) and the percentage of crossovers was determined by means of the product method. A crossover percentage of 42± 0.28 was obtained in the repulsion phase. Unfortunately the backcrosses were not of a type which would provide further information regarding linkage of characters with the abnormal flower mutant.

TABLE V—SEGREGATION IN F_2 FOR INDETERMINATE VERSUS DETERMINATE PLANT HABIT (SP SP) AND NORMAL VERSUS ABNORMAL FLOWER TYPE (PS PS)

Population No.	F_2 Plants in Class				P for Goodness of Fit to 9:3:3:1 Ratio
	Sp Sp		sp sp		
	Ps Ps	ps ps	Ps Ps	ps ps	
1-S	279	79	81	26	0.30–0.50
2-S	558	184	191	36	0.01–0.02

TABLE VI—CHI SQUARE TESTS FOR INHERITANCE OF PLANT HABIT (SP SP) AND FLOWER TYPE (PS PS) IN F_2 POPULATION 2—S

Population No.	Goodness of Fit for	df	X^2	P
2-S	9:3:3:1	3	10 77	0.01–0.02
	3:1 Sp sp	1	1.28	0.20–0.30
	3:1 Ps ps	1	2.72	0.05–0.10
	Linkage	1	6.77	0.01

The observed values for the homozygous dominant and the two heterozygous classes are in relatively close agreement with the calculated. Approximately one-half of the calculated number of homozygous recessive progenies were obtained, however, in population 2–S. The simple recessive form *ps ps* in both F_2 populations was consistently less frequent than expected (Table II). This might indicate a probability of having fewer viable gametes in the recessive flower form and particularly in the double recessive *sp sp, ps ps* of population 2–S.

The presence of the homozygous recessive *ps ps* in the seed may have caused a reduction in viability. Results of a germination test were indicative of a lower viability of seeds from the mutant (72 per cent) and of a slower rate of germination. Populations 1–S and 2–S germinated 96 and 92 per cent respectively. It is possible that a larger part of the non-germinated material was from the *ps ps* progenies.

The genes for immature fruit color and plant habit are located on chromosomes IV and VII (8, 10), respectively. The factor for flower type is either not located on chromosome IV or is at such a distance from the *Uu* factor as to be independently inherited. Although statistical evidences of linkage between flower type and plant habit were obtained in F_2 population 2–S close observation reveals that only the completely homozygous recessive class was greatly different from the

expected (Table V). Population 1–S indicated independent segregation of the two factors. It is unlikely that the gene for flower type is associated with the known linkage group of chromosome VII.

TABLE VII—TIME STUDY IN THE PRODUCTION OF HYBRID SEED

Attempted Cross	Pollination Time (Hours)	Repeat Pollination Time (Hours)	Number Pollinations	Number Fruits Set	Mean Number Seeds Per Fruit	Per Cent Fruit Set	Calculated Time Required to Produce One Ounce† Hybrid Seed (Hours)
JBS × Earliana*	6.25	4.50	864	567	96	65.6	1.58
JBS × Earliana*	1.00	0.50	112	65	96	58.0	1.92
JBS × Earliana**	6.50	0.00	778	476	96	61.2	1.14
JBS × Pritchard*	4.00	1.75	451	316	96	70.0	1.52
JBS × Pritchard*	3.75	0.00	403	292	96	72.5	1.07
Pritchard × Earliana	9.00	1.00	434	194	83	44.7	4.97
Earliana × Valiant	5.75	1.50	306	40	51	13.1	28.43
Rutgers × Pritchard	6.25	2.00	409	63	75	15.4	13.97
Rutgers × Pritchard	4.00	1.25	244	114	75	46.7	4.91

*Some emasculation.
**No emasculation.
†8000 seeds per ounce.

TECHNICS IN HYBRIDIZATION

Inasmuch as the danger of normal self pollination is practically eliminated by use of the mutant character, in the production of hybrid seed, it is possible to allow the blossoms to reach full maturity before pollinating. This results in greater assurance of having a high percentage of fertilization and greater fruit set. In addition it is possible to pollinate practically all of the blossoms on each cluster at one time, while the mean number of immature normal flowers that can be hybridized at one time is commonly two to the cluster.

In allowing the entire flower cluster of the mutant to mature before pollinating, it is sometimes necessary to emasculate the blossom in order to have access to the stigma. The loss in turgidity of the older blossoms causes a relaxing of the apex of the corolla inwardly resulting in complete overlapping of the stigmatic surface. The zone of attachment of the corolla and anthers to the receptable is brittle, however, and if emasculation is desired it is accomplished in one operation. Inserting the tip of the thumb nail into the anther tube, twisting slightly, then lifting will result in complete removal of the corolla and the anthers.

Technic studies with this line during 1947 indicated that crossed seed could be produced many times more rapidly than with normal blossoms. Table VII indicates the results of a hybridization time study.

The estimated mean time required to produced an ounce of seed is 1.45 hours with the mutant as the female parent and 13.07 hours with the normal. The extreme variation in percentage of fruit set on the normal varieties is due primarily to environmental conditions. These variations have been pointed out by Oba, Riner, and Scott (11), although the differences found by them were much less than are shown in Table VII. With a determinate vined variety that normally sets

well under field conditions at Cheyenne, Wyoming, they found it possible to produce an ounce of seed in 3.4 hours with unshaded plants and 2.4 hours with shaded plants. Other workers have indicated that 8 to 9 hours are required for one person to produce an ounce of crossed seed (1, 6).

The data suggest that it may be disadvantageous to spend time in re-pollinating, but rather to use that time in making a greater number of crosses. Using the mutant, an ounce of crossed seed was produced in an average of 1.10 hours when no re-pollinations were made, whereas it took an average of 1.67 hours where re-pollination was practiced.

No difficulties are evident in maintaining the recessive mutant. Artificial self pollinations are easily made and ample seed is produced.

In an effort to devise an efficient method for applying pollen, suspensions of pollen grains in various solutions were sprayed onto the blossoms. This method has been relatively unsuccessful because of pollen grain rupture, but enough seed was obtained by using suspensors of beta napthoxyacetic acid, 75 mg or alpha naphthalene acetamide, 50 mg per liter of distilled water, to warrant continued investigations. The use of dry diluents as suggested by Snyder (16) for applying apple pollen also might offer possibilities. In the development of either method, however, it is imperative that an efficient system for collecting pollen in quantity also be devised. The use of an electric vibrator as reported by Oba, Riner, and Scott (11) is apparently the most effective system at present.

Discussion

Barrons (2), and Barrons and Lucas (1) expressed the opinion that F_1 hybrid tomato seed production by commercial seed concerns would be delayed because of high costs and difficulties involved. They suggested the possibilties of utilizing male sterile mutants as the female parent and of maintaining the stock by means of asexual propagation. Larson and Currence (6) also suggested alternative methods of hybrid seed production including the use of the second filial generation or the use of male sterile lines. They suggested a program for transferring the type of sterility reported by Lesley and Lesley (7) to strains having good combining ability; asexual propagation methods were then to be used in maintaining the new lines.

Maintenance of lines by asexual means is not desirable in tomato because of susceptibility to virus infection. A method of sexual maintenance would be much more advantageous.

Powers (12) pointed out the possibilities of applying the results of Turnovski's and Missura's (17) experiment with X-ray irradiated tobacco seed. These researchers found that a certain percentage of the treated seed produced male sterile plants. Powers suggested then that tomato seed of those strains desirable in hybrid production should be X-rayed and a large population grown. In this manner male steriles could be obtained in any line desired.

Rick in his survey of cytogenetic causes of unfruitfulness in the tomato (13) suggested that genetic male sterile mutants, depending

on simple recessive genes, may be most advantageous in hybrid tomato seed production. He stated that selection in large varietal plantings for the male sterile characteristic can be done more quickly than following the traditional method of backcrossing. His observations indicate a gametic mutation rate of approximately 0.02 per cent for 2 n male steriles, or the possibility of obtaining one male sterile diploid in 5000 plants. Inasmuch as these materials must be maintained by backcrossing which will segregate only 50 per cent male sterile progenies it is suggested that morphological abnormality of the flowers causing unfruitfulness would offer greater possibilties in a hybrid tomato seed production plan. The time delay caused by the necessity of transferring this abnormality to lines having good combining ability is a disadvantage but can be reduced to a minimum. By backcrossing without selfing and without selecting the complete recessive after each backcross, but rather by maintaining a large enough number of lines to be assured that the heterozygous type is backcrossed, it should be possible to transfer the mutant characteristic within a period of 4 years, assuming two generations a year.

Since a greater portion of homozygous normal lines will be obtained from each backcross generation it would be necessary to increase the number of plants in the program with each succeeding step. A breeding plan is suggested in Table VIII.

Rick (13) reported that of the 14 sterile diploid plants he studied, three plans were aberrant also in gross morphology, and three plants

TABLE VIII—A SUGGESTED BREEDING PROGRAM FOR TRANSFERRING THE RECESSIVE STERILITY TO LINES OF GOOD COMBINING ABILITY

Genotypes and Proportion of Parental Lines	Segregation of Genotype	Probable Number of Plants to Use in Each Line
Ps Ps × ps ps		
Ps ps × (Ps Ps)	1 Ps Ps : 1 Ps ps	4
1 Ps Ps : 1 Ps ps × $(Ps\ Ps)_2$	3 Ps Ps : 1 Ps ps	4 from each BC plant or 16
3 Ps Ps : 1 Ps ps × $(Ps\ Ps)_3$	7 Ps Ps : 1 Ps ps	4 from each BC plant or 64
7 Ps Ps : 1 Ps ps × $(Ps\ Ps)_4$	15 Ps Ps : 1 Ps ps	4 from each BC plant or 256
15 Ps Ps selfed	61 Ps Ps	4 from each line or 1024
1 Ps ps selfed	2 Ps ps	
	1 ps ps	
ps ps selfed	ps ps	100 from each line or 400

exhibited genetic male sterility in each case conditioned by a single recessive gene.

The possibility is suggested that quantitative changes might occur in conjunction with sterility in the latter plants, and might offset the known combining ability of the strain that the sterile plants represent. If this is logical, it would be imperative that these plants be recombined with the desirable characters of the original strain. This in turn would probably require adequate backcrossing.

Although the percentage of natural self pollination in the flower mutant is very small, the addition of another simply inherited recessive characteristic that could be identified in the seedling stage might be advantageous. The discarding of seedlings showing this characteristic would eliminate the danger of any selfed materials being used in production of commercial crops. Such a possibility was suggested by

Currence (4) in his study of semi-sterility caused by an elongated style.

SUMMARY

A morphological flower mutant obtained from the John Baer variety, causing or associated with functional sterility is described.

The characteristic was found to be inherited as a simple recessive to which the gene symbol *ps* was assigned. An analysis of the combined inheritance of immature fruit color *Uu* and flower type *Ps ps* indicated independent segregation. It is unlikely also that the factor for plant habit *Sp sp* is associated wih flower type *Ps ps*.

The advantages of utilizing the functional sterility in hybrid tomato seed production are enumerated and a method of transferring the characteristic to lines having good combining ability is suggested.

A time-technic study indicated that with the use of the mutant an ounce of seed could be produced in 1.1 to 1.7 hours per person.

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Effects on Tomatoes of Field Application of Two Hormone-Insecticide-Fungicide Mixtures[1]

By ELTON F. PADDOCK,[2] *Ohio State University, Columbus, Ohio*

ONE problem of the Yoakum, Texas green-wrap tomato producing area is that of "set". It is especially important since ordinarily only the fruit of the first three clusters matures early enough for marketing. Often a failure of set is assignable to a lack of pollination. Chemically induced parthenocarpy would forestall this. Several chemicals are now known to possess the property of parthenocarpy induction when applied to tomato flower buds (1). One economically feasible way to apply these chemicals on field cultured tomatoes would be to add them to the sprays ordinarily used for insect and disease control. Under these conditions it would necessary to employ chemicals lacking the "formative" effect.

Two such chemicals were used:[3]

1. a(2–chlorophenoxy)propionic acid, referred to below as "2–chloro".
2. a(2,4,5–trichlorophenoxy)propionic acid, referred to below as "trichloro".

Two–chloro was used at 25 milligrams/liter, trichloro at 10 milligrams/liter. Each chemical was applied in two different ways. One way was by adding it to a standard insecticide-fungicide, thus spraying it on all parts of the plants. The other way was in aqueous solution to inflorescences only by means of a perfume atomizer. In a fifth (control) treatment, and in the plots receiving atomizer applications, the standard insecticide-fungicide was applied alone to the whole plants. The formula of the standard spray was always: Copper Hydro 40, 3 pounds; lead arsenate, 3 pounds; Grasselli spreader, 6 ounces; water, 50 gallons. The atomizer applications of the parthenocarpy-inducing chemicals followed as soon as the standard insecticide-fungicide spray had dried (within less than an hour). Two separate atomizers were used throughout the season, always the same one for a given chemical. Three separate Meyer 3-gallon sprayers were used in the same consistent manner as above for the spray mixture alone, the 2–chloro plus spray mixture, and the trichloro plus spray mixture applications. There were three applications during the 1945 season, timed (April 2, 12, 25) for each of the three crops of clusters as its earliest flowers opened. A Latin Square field design was employed at the Tomato Disease Laboratory, Yoakum, Texas. Rutgers variety was planted. Rows were 6 feet apart, but alternate rows were used as barriers, making treated rows 12 feet apart. The rows were oriented on the contour and mostly northwest-southeast such that the prevailing winds blew lengthwise of the rows. There were 20 plants per plot and 25 plots in all, a total of 500 plants.

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[1]Texas Agricultural Experiment Station Technical Article No. 1102.

[2]Formerly, In charge, Tomato Disease Laboratory, Texas A. & M. College, Yoakum, Texas.

[3]Suggested as worthy of testing at the concentrations used and kindly supplied by Dr. P. W. Zimmerman of the Boyce Thompson Institute.

Number of fruits on first clusters was recorded April 30. Second and third clusters were recorded on May 11. Fruits which set but had not developed further were recorded separately from those which had developed (Table I). No record was made of numbers of abscissed

TABLE I—NUMBERS OF FRUITS WHICH DEVELOPED, AND WHICH SET BUT DID NOT DEVELOP, ONE MONTH* AFTER TREATMENT WITH CHEMICAL HORMONES (ALSO TONS PER ACRE OF MARKETABLE FRUIT, TOTAL OF FIRST FIVE PICKINGS. DATA BASED ON STUDY OF FIVE HUNDRED PLANTS)

Treatments	Clusters								Yields**
	First		Second		Third		Totals†		
	Developed	Set Only	Developed	Set Only	Developed	Set Only	Developed	Set Only	
2-chloro									
Atomizer to inflorescences	201	139	292	107	228	95	721	341	1.7851
Spray to whole plants	144	208	85	205	96	156	325	569	0.6136
Trichloro									
Atomizer to inflorescences	251	130	286	120	245	142	782	392	1.8865
Spray to whole plants . .	161	111	3	46	1	16	165	173	0.2611
No hormone (control) .	204	47	275	65	239	89	718	201	1.8737
Totals‡	961	635	941	543	809	498	2,711	1,676	——

*Third cluster recorded 2 weeks after treatment.
**L. S. D., 5 per cent level, 0.61 tons.
†L. S. D., 5 per cent level, developed, 72 fruits.
‡L. S. D., 5 per cent level, developed, 52 fruits.

flowers, but there were very few which did so on the controls. There were highly significant differences in numbers of developed fruits between treatments. In comparison with the control, spray mixture plus chemical application to whole plants seems to have *reduced* the number of developed fruits, while atomizer application to inflorescences only seems to have had no effect. Interaction also was highly significant indicating that first clusters were but slightly affected as compared to later clusters. This is especially evident in the data from spray mixture plus chemical application of trichloro. Number of set fruits, whether or not developed, seem, from inspection of Table I, also to have been reduced from that of the control by the spray mixture plus trichloro applications, while atomizer applications of it seem to have produced an increase. In the case of 2-chloro, an increase resulted from both methods of application. It is interesting to note, however, that the spray mixture plus chemical method of application gave a highly unfavorable proportion of set and developed to set only, while after atomizer application most flower buds set and developed.

Total marketable yields (Table I) from the first five pickings (May 4 to 26, inclusive) showed highly significant differences between treatments. Yield was apparently severely reduced by spray mixture plus chemical application, and unaffected by atomizer application. All yields are low because of a hail storm on May 11 which rendered an estimated 30 per cent of the yield unmarketable. Otherwise the season was favorable and yields would have been normal or slightly better than normal in the controls.

Discussion and Conclusions

The result obtained was opposite to the one hoped for. Application of either parthenocarpy-inducing chemical to whole plants in the respective concentrations used by adding it to a standard insecticide-fungicide mixture apparently reduced the numbers and yields of fruit. Trichloro was especially unfavorable in its reaction. This was obviously a result of a formative effect, detectable as a slight rugosity of the leaves already by the time of the second application. Subsequent to the second application, trichloro treated plants ceased growth (Fig. 1)

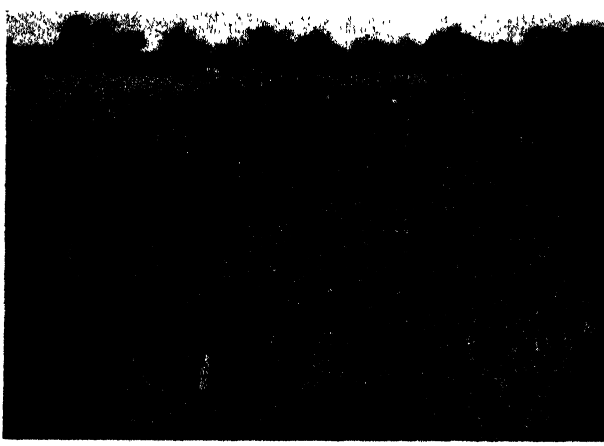

Fig. 1. Stunting effect (foreground) of application to whole tomato plants of (2,4,5-trichlorophenoxy) propionic acid by adding it to a standard insecticide-fungicide spray mixture. Staked plants are in untreated border rows. Photographed two weeks after last application.

except for becoming progressively more gnarled and stunted. The formative effect might disappear with use of a lower concentration of trichloro. Two-chloro did not produce a detectable formative effect. Application of either chemical in the same respective concentrations in aqueous solution to inflorescences only by means of an atomizer apparently had no effect on numbers or yields of fruit. Possibly the desired result might be obtained with other concentrations of these same chemicals, or through use of different chemicals from among the several that are available.

The possibility that one or both chemicals would be inactivated by the insecticide-fungicide mixture did not materialize.

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Effect of Sprout Preventive Treatments on Fall-Harvested Kohlrabi, Potatoes, Sweetpotatoes, and Turnips While in Storage

By C. L. ISBELL, *Alabama Agricultural Experiment Station, Auburn, Ala.*

UNDER Alabama conditions, especially in the central and southern parts of the State, fall-harvested kohlrabi, potatoes, and turnips may be stored over fall, winter, and early spring in the open with comparatively little protection against low temperature. During storage these vegetables make some top and root growth that may cause spoilage. Sweetpotatoes gradually produce sprouts and become somewhat pithy when they remain stored in a house or dry basement over winter, spring, and into early summer. As a phase of a general project to determine best methods of common storage for vegetables on the farm, limited experiments were started in the fall of 1947 and continued into the spring and summer of 1948 to determine the practical value, if any, of treatments with Barsprout (a dust containing methyl ester of naphthaleneacetic acid 2.2 per cent) or Sprout Inhibitor (a dust methyl 1–naphthaleneacetate 2.2 per cent) on the prevention of these undesirable changes. Others have reported on the use of these or quite similar materials for sprout prevention, especially with potatoes and turnips. Specific references are not given because conditions that prevailed with their experiments were different from those reported in this paper.

METHODS AND PROCEDURE

Kohlrabi, Potatoes, Turnips:—At or near the time of harvest, the leaves and roots were removed from White Vienna kohlrabi and the tops from Purple Top White Globe turnips. Approximate duplicate quantities by number and weight of kohlrabi (10 pounds), Menominee and Sebago potatoes (25 pounds each), and turnips (25 pounds), were dusted with Barsprout. Similar quantities were dusted with Sprout Inhibitor and similar untreated quantities were used as checks. The dust was applied from a can with holes in the top, with an effort to apply it uniformly and at the rate of 1 pound to 8 to 10 bushels. These were stored in the open, on a well drained area, by placing them on and covering them with 4 to 6 inches of clean dry pine straw.

A second lot consisting of the same kind and amounts of kohlrabi and turnips that received the same kind of treatments just mentioned was stored in tub baskets in the basement of a field house. A third lot consisting of potatoes was placed in tub baskets, covered with enough hay to prevent freezing, and stored in a barn loft. Observations were made from time to time until the vegetables were considered to be no longer usable or near the end of their storage lives.

Sweetpotatoes:—Porto Rico and Triumph varieties were harvested about October 1 and stored in a house until November 11. At this time four ½-bushel samples of each variety were treated with Barsprout dust, similar quantities were treated with Sprout Inhibitor, and equal quantities were used as checks. All the potatoes in all treatments

remained in the storage house until December 9, at which time one-half of the baskets of each treatment, including the checks, were stored in a dry warm basement. Observations were made on the various lots from time to time untl June 5, and on some as late as August 23, 1948.

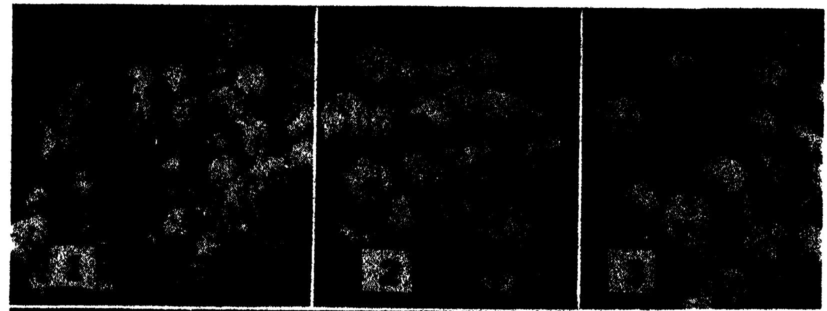
Results

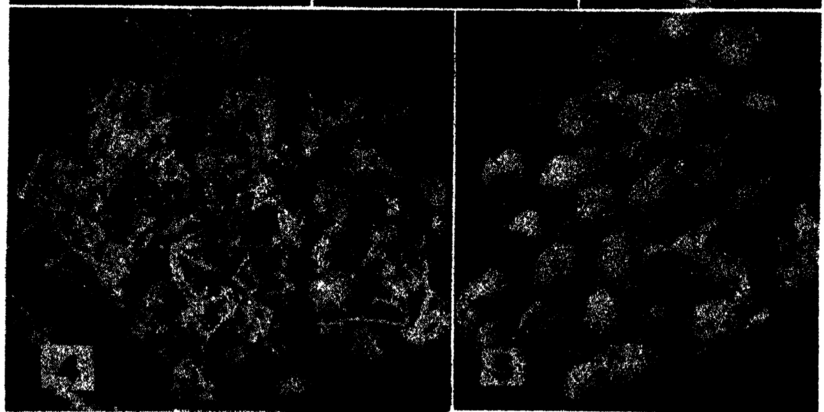
In the case of the vegetables stored under straw in the open, there was some weather damage around the edges of the hill due to the thinness of cover or to disturbances resulting from inspection or other causes. For this reason qualitative rather than quantitative results are stressed.

Kohlrabi:—Barsprout treatment prevented new leaf growth but it caused much proliferation, resulting in a knotty rough product in each place of storage. Those stored in baskets in a field house basement were considered too dry and knotty for use as food. Results of Sprout Inhibitor treatment were similar to those of Barsprout. Although there was some new growth on the checks stored under straw, they appeared to be in best condition at all times. Figs. 1, 2, and 3, respectively, illustrate the comparative condition of the check, Barsprout- and Sprout Inhibitor-treated lots that were stored under straw as they appeared on March 10. This was about as late as any of those in the check lot were usable. At this time about 80 per cent of the checks remained sound, and 30 and 35 per cent, respectively, for those receiving Barsprout and Sprout Inhibitor treatments were sound.

Turnips:—Those treated with Barsprout and those treated with Sprout Inhibitor behaved similarly. The treatment tended to kill the base of the old leaves that remained after the turnips were trimmed preparatory to storing and to prevent or kill new leaf and root growth as it appeared. These treatments caused much proliferation on the surface of the turnips and appeared to cause shrivelling especially with the less mature ones. There was considerable new leaf and top growth on the check lots stored under straw, beginning soon after storing, but at all times the checks under straw appeared to be best for table use. Figs. 4, 5, and 6, respectively, illustrate the comparative condition of the check, Barsprout and Sprout Inhibitor lots stored under straw as they appeared on March 10, about as late as those in the check were considered usable. Fig. 7 shows relative amounts of usable turnips on March 18, from left to right representing check, Sprout Inhibitor, and Barsprout treatment, respectively. At this time when the experiment was discontinued approximately 70 per cent of the checks remained sound and 20 to 50 per cent, respectively, of those receiving Barsprout and Sprout Inhibitor treatments were sound.

Potatoes:—The Menominee variety sprouted somewhat quicker than did the Sebago, under the various treatments, but in general, the behavior of both was similar. Results from treatment with Barsprout and Sprout Inhibitor tended to be very similar. Each of these greatly retarded or prevented sprout development as compared with the check. This difference was great in the case of basket storage in a barn loft, and it was even greater with those stored in the open under straw.

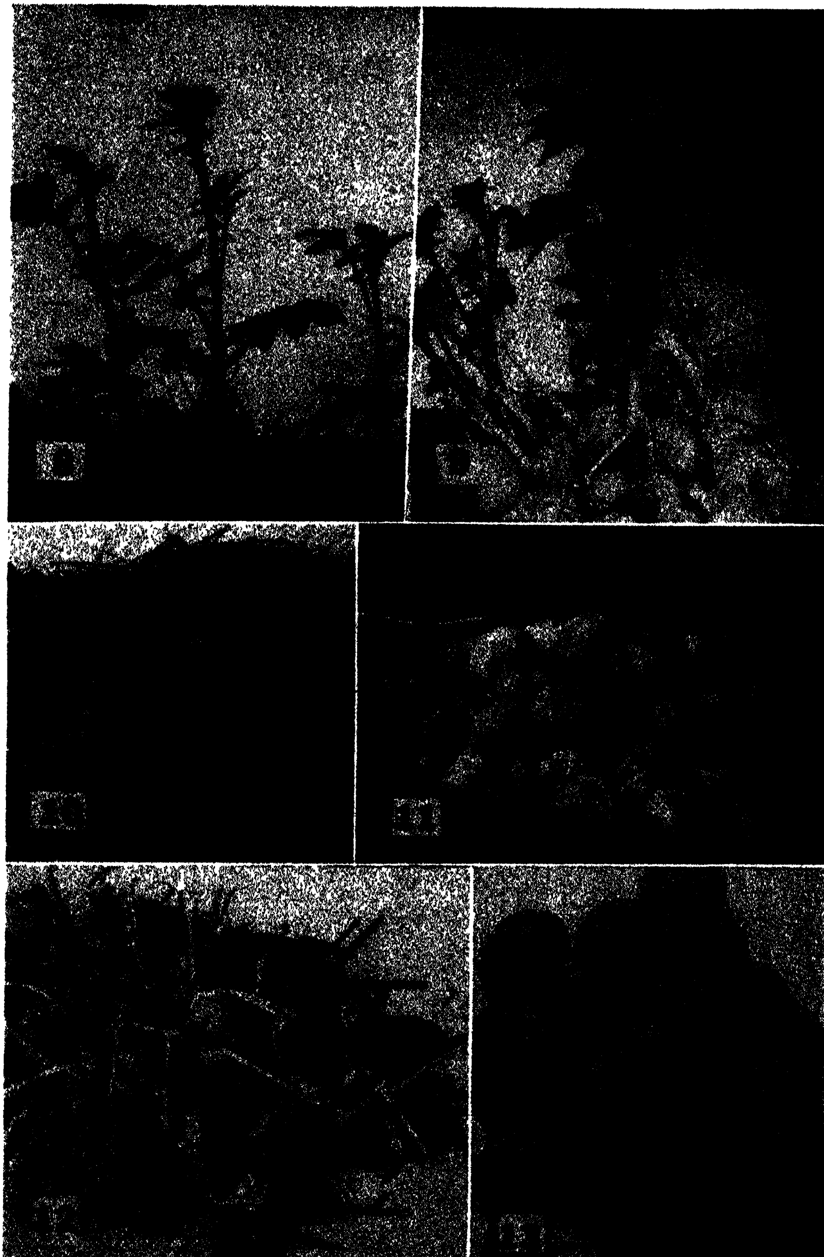




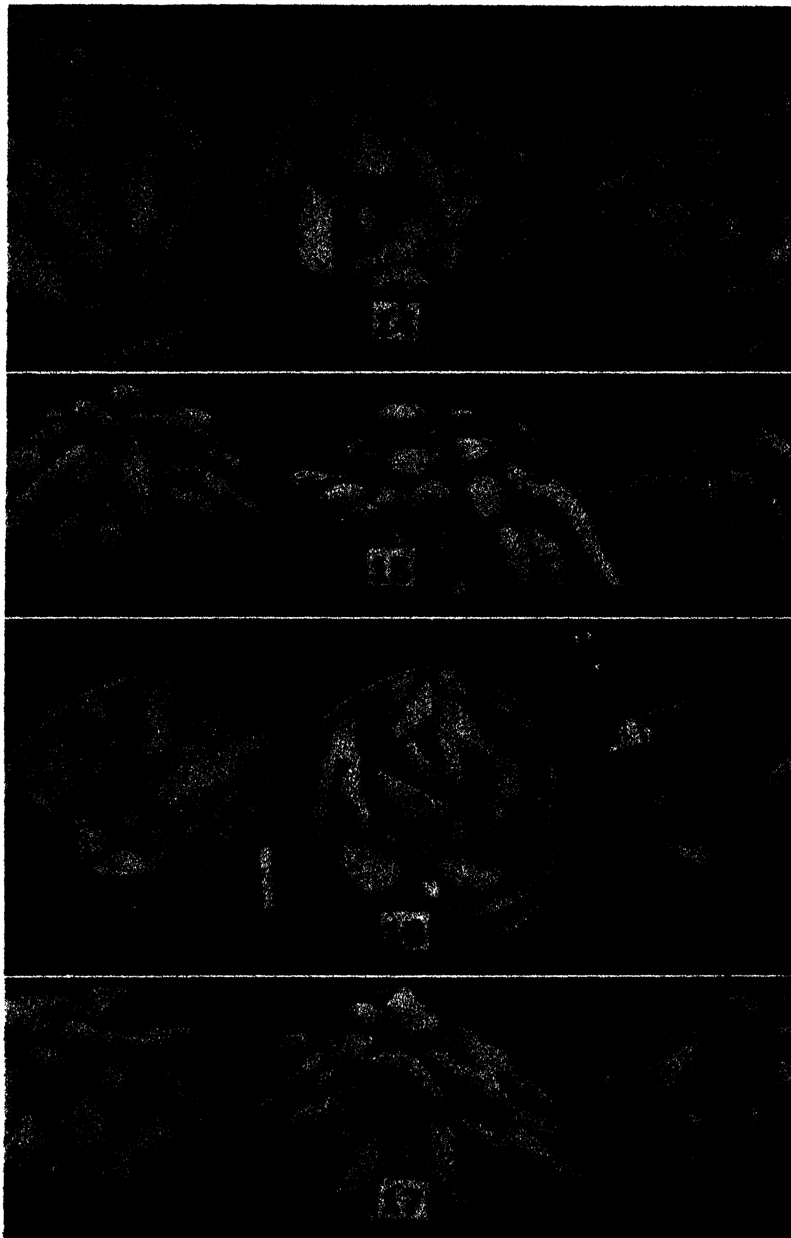
FIGS. 1, 2, and 3 respectively illustrate the condition of Check, Barsprout, and Sprout Inhibitor treated lots that were stored under straw as they appeared March 10 (Kohlrabi).

FIGS. 4, 5, and 6 respectively illustrate the condition of Check, Barsprout, and Sprout Inhibitor treated lots stored under straw as they appeared March 10.

FIG. 7, illustrates from left to right sound turnips March 18, of Check, Sprout Inhibitor and Barsprout treated lots that were stored under straw (Turnips).



FIGS. 8 and 9 illustrate condition of check lots and FIGS. 10 and 11 illustrate condition of Sprout Inhibitor treated lots — all on May 5, all stored under straw. FIGS. 12 and 13 illustrate respectively check and Bar-sprouted lots stored in a barn as they appeared May 7 (Potatoes).



FIGS. 14 and 15 respectively illustrate for Porto Rico from right to left check, Sprout Inhibitor, and Barsprout treated lots stored in a basement as they appeared June 5. FIGS. 16 and 17 respectively illustrate for the Triumph what FIGS. 14 and 15 represent for Porto Rico (Sweetpotatoes).

Figs. 8 and 9, respectively, illustrate the condition on May 5 of the covered and uncovered checks as compared with the Sprout Inhibitor-treated potatoes in Figs. 10 and 11. On that date there was not a great deal of difference in the relative number of sound potatoes in the check and treated lots, but there was a tremendous difference in the qualitative conditions as shown by the illustrations. Figs. 12 and 13, respectively, illustrate check and Sprout Inhibitor-treated samples stored in baskets in a barn as they appeared May 7.

Sweetpotatoes:—Results from storing sweetpotatoes treated with Barsprout or Sprout Inhibitor and stored in the house or basement appeared to be similar. There were some indications that sweetpotatoes well covered with either dust tended to sprout more slowly than those of the check. The inhibiting tendency appeared to be much greater with the Triumph variety, which naturally sprouts more slowly than the Porto Rico. Some of those stored in the house were disturbed and injured by rats. Those stored in the basement were not; therefore, only results for those stored in the basement are presented.

By June 5, 98 to 100 per cent of all the Porto Rico and the Triumph checks stored in the basement had sprouts showing or rather well developed. On the same date only 60 to 70 per cent of the treated Triumph had sprouts visible or developed. The Porto Rico, as of that date, is shown in Fig. 14 with check on the right, Sprout Inhibitor treatment in the center and Barsprout treatment on left. In Fig. 15 the same ones are spread out to show sprouts. Figs. 16 and 17 show, respectively, for the Triumph variety what Figs. 14 and 15, respectively, show for the Porto Rico variety. One check lot each of Porto Rico and Triumph was utilized before August 23. On this date the potatoes of the remaining check lots and all those of the treated lots were reexamined for sprouts and cut to determine their possible value for food. The sprout behavior was similar to what it was on June 5. There were insufficient data to establish whether treatments influenced internal spoilage favorably or unfavorably. However, there were enough to suggest that this point should be carefully determined before any recommendations are made.

Summary

This paper briefly presents results of an experiment on sprout-preventive treatments by means of Barsprout and Sprout Inhibitor dust when used on fall-harvested and stored kohlrabi, potatoes, turnips, and sweetpotatoes. The results tend to indicate the following:

1. Barsprout and Sprout Inhibitor tend to give the same general results for any of the specific vegetables mentioned, provided the vegetable was stored under similar conditions.
2. Kohlrabi and turnips that received no treatment were as good, when stored in baskets in the basement of a field house, and were better when stored under straw in the open than were those treated with either Barsprout or Sprout Inhibitor and stored under similar conditions.
3. Potatoes receiving either Barsprout or Sprout Inhibitor treatment and stored in baskets in a barn loft sprouted and shrivelled

much more slowly than the untreated checks. Potatoes receiving either Barsprout or Sprout Inhibitor treatment when stored under straw in the open developed sprouts very much more slowly than untreated checks.

4. The use of either Barsprout or Sprout Inhibitor dust thoroughly applied appeared to delay sprout appearance on the Porto Rico and definitely delayed it on the Triumph sweetpotato when stored either in a house or in a dry basement; however, the internal condition of the potatoes in late summer indicated that more extensive experiments would be necessary before recommendations can be safely made concerning the advisability of sprout preventive treatments with sweetpotatoes.

The Southern Tomato Exchange Program

By S. H. Yarnell, *U. S. Regional Vegetable Breeding Laboratory, Charleston, S. C.*

By and large, adaptability and marketability are the two chief concerns of the plant breeder. Since both attributes are essential to the success of a variety, it is fruitless to say that one is more important than the other. Of the two, those characteristics contributing to marketability can in general be seen, tasted, or weighed, and therefore fairly readily identified. In contrast to this, those aspects contributing to adaptability, with the exception of yield, are less obvious and therefore often harder to recognize. The fact that environments, as well as plant materials, are highly complex and vary widely over a region such as the Southern States, further complicates the problem of the breeder who would introduce a commercially successful variety.

In order to avoid confusion it might be well to say that adaptability is here used in its broadest sense to include not only the ability to produce well in a given climate and soil, but under such conditions to have desirable quality and also to carry disease resistance. Uniformity under a particular set of environmental conditions is a much needed and sometimes neglected aspect of adaptability.

After the breeder has produced what appears to be a successful new variety and the time comes for its introduction he may find that his troubles are not entirely over. Market requirements, for example, are often conditioned by certain peculiarities of the human race, such as the urge to follow eating habits of long standing and its corollary, the disinclination to try something new. The seedsman also demands certain qualifications. The new variety may be well adapted in a very limited area. The grower demand for its seed would then be relatively small. As a consequence seed production might be too costly to compete with seed of established varieties. In some cases, and this is especially true of tomatoes, seed production may be closely tied in with the processing of the fruit — an activity that may not be carried on commercially in the area where the new variety has been shown to be adapted. As a final item of discouragement, it might be pointed out that even in the area where the variety is best adapted the seasons vary widely; and since a new variety can hardly have stood the test of time, it may not hold up as well during adverse seasons as expected.

These and other considerations to be brought out later have formed the basis for a series of cooperative variety tests established by horticulturists, pathologists, and vegetable breeders in the South. While especial attention will be given to the tomato variety trials, known as the Southern Tomato Exchange Program, the principles involved are much the same for the other cooperative vegetable trials.

This type of program grew out of discussions of those attending the annual meetings of collaborators at the United States Regional Vegetable Breeding Laboratory at Charleston, South Carolina, and has been further developed at conferences held by the Southern Section of the American Society for Horticultural Science. The cooperative tomato variety tests, which will be referred to as the STEP trials,

were initiated at a conference held at the Francis Marion Hotel at Charleston on the evening of October 25, 1945. Among those present were C. L. Isbell of Alabama; V. M. Watts of Arkansas; A. L. Harrison of Florida; W. S. Anderson, J. L. Bowers, J. A. Campbell, and H. H. Foster of Mississippi; E. F. Paddock, B. S. Pickett, and S. H. Yarnell of Texas; and C. F. Andrus representing the Vegetable Breeding Laboratory. Discussions were continued the following day at the Laboratory, at which time C. F. Andrus was named chairman of the group.

It should be noted that this group included plant breeders and pathologists, as well as horticulturists with a major interest in commercial tomato production. The estimation of the value to southern growers of varieties introduced by seedsmen was one of the objectives of the work. The inclusion of a number of pathologists insured proper attention to the important aspect of disease resistance, and the fact that a pathologist who is also a tomato breeder became chairman of the group emphasized the desire for a continued consideration of the disease resistance of new varieties.

Observation of a large group of varieties, each from a common seed source, over a region as large as the Southeastern States has certain definite advantages not to be obtained from even comprehensive tests at a single location. Most obvious perhaps is that in a single season the effect of differences in climate can be observed that ordinarily would require several years at a single location. Of greater importance is the test of adaptability to a range of environmental complexes involving both soil and climate and whatever else may enter into what is known as the "place effect". A test over a period of years at one location, no matter how many replications are used, does not serve as an adequate substitute for this purpose. Another feature, related to adaptability, is change in the appearance of both plant and fruit under diverse environments. This may be seen as fairly uniform differences under the different environments, or a variety may be highly uniform under one set of conditions and variable under other conditions. Further, in such cooperative tests, varieties are subjected to a much wider range of diseases than would be likely to occur at a single location over a period of years. Finally, a cooperative program of this type facilitates the inclusion of varieties newly introduced and also provides a great variety of materials as yet unintroduced and normally unavailable for wide testing.

Probably the group to receive the greatest benefit from this type of undertaking is the breeder with material nearing the stage of introduction. This value may not be immediately apparent to the individual immersed in the selection of desirable gene accumulations, such as combinations of high yielding capacity with good eating quality, with desirable appearance, and with resistance to disease. But when the time for introduction is at hand, evidence for wide adaptability secured in these trials is useful to the grower and seedsman alike, and gives weight to a bid for a place in the commercial field. It is this grower-interest in the new varieties that justifies the horticulturist who is not also a breeder in taking the time to include these breeding lots so as

to sift the catholic from those only locally adapted. It is perhaps significant that the crops with which this type of program has made the greatest headway are the ones with which the greatest number of workers have a breeding program.

The general plan of the STEP trials is as follows: *1.* All previously untested lines that are to be included in the program are grown in unreplicated planting, the size of which is determined by local practice. This combines the features of a comprehensive survey of much material with a minimum amount of work for each individual. The relatively large number of cooperators compensates to a considerable extent for the lack of replication on first planting. *2.* The second year all lots are placed in one of three classifications — (a) those worthy of inclusion in a small replicated planting, (b) those to be grown again in the more extensive observational planting, and (c) those in which there is no further interest. Decision for the final grouping is made by the chairman with the advice of the collaborators on the basis of the combined reports. *3.* A few standard commercial varieties are grown every year for purposes of continuity and comparison. It has been found convenient and effective to record the behavior of the lots under test in terms of the results secured with a standard reference variety. Thus, any characteristic of a variety or selection under test may be as large as, or as good as, or better or poorer than the variety selected for comparison. No emphasis is placed on yield for the unreplicated plantings. *4.* The material to be tested is collected by the chairman and distributed by him to the cooperators. This insures that all have identical samples. There are two main sources of material for testing. These are the seed companies and the Southern cooperators carrying on breeding programs. Other possible sources are tomato breeders outside the Southern area and home gardeners who have made selections and saved their own seed over a considerable period of years. *5.* Between seasons, which is a comparatively brief interlude in the South, the chairman issues a detailed mimeographed report of the results secured during the preceding year. The report for the 1947 STEP trials consists of 13 large-size pages and was issued on December 31. Further mention will be made of this in the discussion of results.

It might be worth while here to spend a little time on the forms used for reporting the results, as those define the scope of the work more precisely. In both the replicated and unreplicated trials Rutgers has been chosen as the reference variety. The qualities considered in the unreplicated or observational trials may be found in Table I. It will be observed that the exact category depends upon the degree of development of the reference variety with respect to the character under consideration. The outline for the replicated trial (Table II) is similar to the one just described except for a greater emphasis on productivity and on fruit size. The former is given in pounds of marketable fruit per acre. The latter is divided to give the size of fruit during early harvest and size during late harvest. There is also additional space for notes on disease resistance. Four or more replications are ordinarily employed in this test.

TABLE I—FORM USED FOR TOMATO OBSERVATIONAL TRIALS

Station Reporting ______________________ Crop Season ______________________

		Earliness				Productivity				Fruit Size				General Appear.				Uniformity		Disease Resistance, Etc.			
	No plants observed	Extra early	Earlier than Rutgers	Same as Rutgers	Too late	Better than Rutgers	Equal to Rutgers	Less than Rutgers	Too unproductive	Larger than Rutgers	Equal to Rutgers	Sl. sm. than Rutgers	Too small	Better than Rutgers	Equal to Rutgers	Not equal to Rutgers	Poor	Satisfactory	Definitely mixed	1 = Definitely resistant 2 = Less injury than the general average 3 = Moderately susceptible 4 = Very susceptible (Insert name of disease with rating, such as Septoria 3, Bacterial Wilt 1, etc.)	Should this line be incl. in repl. trials?	Should it be repeated in obs. trials?	Check the 2 best tomatoes in this trial
Rutgers																							

Mail one copy to the Vegetable Breeding Laboratory, Box 844, Charleston, S. C. by December 1st.

TABLE II—FORM USED FOR TOMATO REPLICATED TRIALS

				Size Early Harvest				Size Late Harvest				Earliness				General Appear.				Uniformity	
	No. repl.	Pls. per repl.	Average Market Yield	Larger than Rutgers	Equal to Rutgers	Sl. sm. than Rutgers	Too small	Larger than Rutgers	Equal to Rutgers	Sl. sm. than Rutgers	Too small	Extra early	Earlier than Rutgers	Same as Rutgers	Too late	Better than Rutgers	Equal to Rutgers	Not equal to Rutgers	Poor	Satisfactory	Slightly irregular
Rutgers																					

	Disease Notes	Comments
Rutgers		

Which do you consider the best tomato in this test?________________
Station reporting________________
Please return to the Vegetable Breeding Lab., Charleston, S. C. by December 1st.

This past year completed the second season of the STEP trials. During the first year records were obtained on 41 new tomatoes grown at 19 widely spaced locations. These ranged from Beltsville, Maryland, to the lower Rio Grande valley of Texas, and from Perkins, Oklahoma, to Bradenton, Florida. There were, in addition, plantings in Hawaii and Puerto Rico. All of the entries were unreplicated the first season. As a result of this work eight lines were selected for the replicated planting during the second season. These included one from Beltsville, one from Arkansas, one from Mississippi, three from the Regional Vegetable Breeding Laboratory at Charleston, and two from Florida. Rutgers, Grothen Globe and Pearson S were grown for comparison. In addition to the replicated trial, which was carried at 22 locations, there were 43 lines in the observational planting the second season. The latter test was grown at 26 different places.

Four of the eight lines in the replicated test, designated as STEP 10, 14, 22, and 24, have sufficient merit to continue another year. This judgment is based upon the ability to produce well over a large area, indicating wide adaptability to soils and climate, upon fruit size, shape, and color, upon vine type, and upon resistance to disease. STEP 10 from Arkansas ranked third in production in spite of a rather small fruit (or perhaps because of this characteristic). It is resistant to fusarium wilt and appears to be of high quality. STEP 14 from Mississippi did well in Florida and in Southwest Texas. Its disadvantages are a lack of uniformity and a susceptibility to early blight. STEP 22 and STEP 24, both from the Regional Vegetable Breeding Laboratory, produce well over a wide area, the latter being first in yield and over-all rating. The former has high resistance to fusarium wilt and collar rot and is somewhat resistant to early blight and late blight. It is hoped that STEP 22 can be released in 1949 and STEP 24 perhaps a year later.

In general, fruit size was highly variable, although for the varieties in the replicated trial the fruit averaged at least as large as Rutgers. The entries from Arkansas and Mississippi are both earlier than Rutgers, and the others have about the same season. This is perhaps to be expected in view of the importance of earliness and the fact that Rutgers is not a first-early variety. Most of the cooperators considered STEP 10 from Arkansas and 22 and 24 from the Regional Vegetable Breeding Laboratory to equal Rutgers in appearance.

Table III, from the 1947 Report by C. F. Andrus gives a very good picture of the kind of results that are being obtained in the replicated trial. The average acre yield of marketable fruit from all points varied for the several varieties from 8,799 pounds to 13,075, this last figure being slightly although not significantly above the yield of Rutgers. The differences obtained with respect to the other characters at the various locations illustrate rather strikingly the nature of this cooperative experiment, involving as it does such a variety and diversity of environments. Many of the same varieties are listed as too small at some places, and larger than Rutgers at others; too late at some locations, and extra early at others; poor in general appearance at some, and better than Rutgers at others. Since we are dealing with

TABLE III—Form Used for Summarized Data on Replicated Trials

1	2	3	4	5 Size Early Harvest				6 Size Late Harvest				7 Earliness				8 General Appearance				9 Uniformity		10
Variety	No. of Locations	Rank in Yield	Average Market Yield (Lbs Per Acre)	Larger Than Rutgers	Equal to Rutgers	Sl Sm Than Rutgers	Too Small	Larger Than Rutgers	Equal to Rutgers	Sl Sm Than Rutgers	Too Small	Extra Early	Earlier Than Rutgers	Same as Rutgers	Too Late	Better Than Rutgers	Equal to Rutgers	Not Equal to Rutgers	Poor	Satisfactory	Slightly Irregular	Best in Test
Rutgers	19	3	12,772		✓				✓				✓				✓			10	0	2
Grothen's Globe	19	7	11.448	2	9	7	0	1	8	6	0	2	10	5	1	1	3	12	2	15	2	0
U. S. No. 24	19	9	10,892	4	13	2	0	2	11	3	0	0	7	9	4	5	11	4	0	16	3	2
Pearsons	19	2	12,987	8	8	2	0	1	12	3	0	0	6	8	5	1	8	9	1	15	3	2
STEP 10	18	5	12,115	2	5	9	1	0	6	6	3	0	4	12	2	2	11	4	0	16	1	3
STEP 14	16	8	11,034	5	5	6	1	0	5	4	5	3	10	5	0	2	3	9	4	9	8	3
STEP 18	19	6	12.065	8	9	2	0	2	8	6	0	1	13	5	1	1	4	13	1	16	3	0
STEP 22	19	4	12,414	3	4	11	0	0	7	6	3	1	5	11	2	2	10	7	0	16	2	4
STEP 24	19	1	13,075	2	6	9	1	0	7	8	1	0	5	13	1	1	11	7	0	17	1	5
STEP 37	18	10	9,899	7	8	3	1	5	8	2	1	0	5	9	6	1	9	8	2	17	0	1
STEP 38	17	11	8,799	10	5	1	1	3	8	4	0	0	5	9	4	1	7	8	2	17	0	2

Variety	Disease Notes						Comments
	W	Eb	Lb	St	Crack	Mosaic	
Rutgers	3–4	2–4	3	3	—	—	
Grothen's Globe	1–4	3–4	3	3	4	—	Several complaints on the quality of Grothen's.
U. S. No. 24	1	2–3	4	2	—	—	Good but not outstanding in productivity.
Pearson S.	1–4	2–4	3–4	4	—	—	Several complaints of poor internal quality.
STEP 10	1–2	2–3	3–4	2	2	—	Small size, less crack, and superior internal color were noted.
STEP 14	3–4	1–4	3	3	—	—	Several complaints of poor foliage cover. Definitely mixed.
STEP 18	3–4	1–4	3	3	—	—	Fruit too flat; unattractive.
STEP 22	1	1–3	2	2	—	—	Tendency to catface. Most resistant to early blight.
STEP 24	1	1–3	4	2	—	—	Apparently has the widest range of adaptation.
STEP 37	1	2–3	4	2	—	—	Vigorous vines but generally unproductive.
STEP 38	1	2–3	4	2	—	—	Vigorous vines but generally unproductive.

biological materials under widely different growing conditions, the range exhibited by the results is expected. Such diversity emphasizes the importance of the agreements obtained. As many as 10 or more workers are found to be in agreement in a good many instances. The general appearance of Grothen's Globe is a case in point. Since 12 observers rated Grothen poorer than Rutgers in this respect under 12 different growing conditions, any claim to the contrary, even based on experimental evidence, as it was in one case, is singularly unimpressive. In the same way, a statement that U. S. 24 fruit compares favorably in size with that of Rutgers, when the nature of the test is considered, is bound to receive wide acceptance.

In a sense it is the old story of heredity versus environment all over again. Here the environment is invited to do its worst to all the hereditary stability of commercially important characters that the plant breeder is able to instil into his material. And the results secured represent a relatively prompt and fairly conclusive judgment in each case.

The replicated trial for the 1948 season will include Rutgers and Grothen Globe as standard varieties, the four selections from the 1947 replicated trial, and in addition five lines selected from the 1947 observational trial. These five newly selected lines come, one each, from Arkansas, the South Carolina Truck Station at Charleston, Hawaii, Beltsville, and the Regional Vegetable Breeding Laboratory. There will be 33 lines in the next observational trial. One planting will be made in Missouri.

After two seasons it is fairly obvious that the purposes for which the STEP trials were organized are being accomplished. Many tomatoes are being tried, with diverse results at the different locations as is to be expected. A few are being chosen for their excellence and wide adaptability. Out of 79 new tomato lines entered in the trials during this period only 11 survived one season's testing, while five have survived two years. It seems likely that material of the type selected will be used more and more widely as a basis for future breeding, with a consequent wider adaptability for the resulting breeding lines. This would mean an increase in efficiency for the breeder as he could then concentrate on the incorporation of desired horticultural characters into material known to be widely adapted.

Thanks are due C. F. Andrus, chairman of the project, for supplying much of the information here presented.

Effect of Frequency of Picking Tomatoes on Yield and Returns[1]

By JOHN HARTMAN and ERIC OESTERLE, *Purdue University, Lafayette, Ind.*

IT is common practice in Indiana to pick tomatoes once every 10 days or 2 weeks, although naturally this schedule may be changed considerably due to weather or the availability of labor. The scarcity of labor has created new interest in the possibility of picking tomatoes less frequently than is normal without losing much of the tonnage which would be obtained by following standard practice. Pickers who are paid by the basketful generally want to delay each harvest because presumably, the greater the delay the more ripe fruit there will be on an acre and the more baskets can be filled by each worker in a day. Canners also have often favored making fewer pickings in the hope that with more ripe fruit in the field, the pickers will tend to leave fruit that is not colored sufficiently to make the U. S. No. 1 grade. Even growers have an interest in reducing the number of pickings, other than satisfying the pickers and the canners, for less frequent picking means less time spent in supervising labor and hauling tomatoes. Of course if a higher percentage of U. S. No. 1 fruit were obtained by a different timing, this benefit would reflect to their advantage.

TREATMENTS AND CONDITIONS OF EXPERIMENT

Tomatoes were harvested according to the following three schedules in an experiment conducted at Montmorenci, Indiana in 1947:

1. Picked at weekly intervals.
2. Picked at bi-weekly intervals except whenever heavy frost seemed imminent; then picked whenever there seemed to be ¾ ton of ripe fruit per acre on the plants.
3. Picked for the first time about September 30th or whenever heavy frost seemed imminent; thereafter picked again whenever plots of Schedule 2 were picked.

The experiment was located in a large field of Indiana Baltimore tomatoes grown by the Klondike Canning Corporation. The land, a dark prairie soil, had been in corn in 1946 and in sod in 1945. Seed was sown directly in the field on May 12. Seven hundred pounds of 2–12–6 commercial fertilizer were applied on each acre, half at seeding and half as a side dressing at the first cultivation. During the growing season, three applications of a copper-arsenical dust were applied with ground equipment.

Originally it was planned to have a total of six treatments in this experiment. Of these, four were to have been picked according to Schedule 1. The plots of one were to have been defoliated with calcium cyanamide of another with sodium cyanamide and of a third with potassium cyanate, while the plots of the fourth treatment were to receive no application of defoliant. However, in spite of the use of a copper dust, all vines lost most of their leaves by September 24th, so there

[1]Purdue University Agricultural Experiment Station Journal Paper No. 352.

seemed no point in carrying out the treatments designed to remove leaves artificially. Four of the treatments were therefore actually the same, and their average yields were simply repeated measurements of the effect of picking by Schedule 1.

The experimental design was a 6 x 6 Latin square. Each plot was 60 feet by 10.5 feet. Very dry weather prevailed during most of September. Light frost injury occurred on September 24th. Many ripe or nearly ripe tomatoes fell from the vines, especially on the plots picked according to Schedule 3. Removal of the calyx from such dropped fruits was time-consuming.

Accurate grading according to the U. S. standards for cannery tomatoes was done immediately after the tomatoes were weighed.

Results and Conclusions

Data presented in Table I show that, for the whole season, Schedule 1, which involved picking every week gave total yields somewhat higher than any other schedule and Schedule 2 ranked second in this respect. The differences between Schedules 1 and 2 were not significant, but those between Schedule 3 and either of the other two frequencies of picking were significant at the 1 per cent level. These conclusions are valid for total yields up to September 25th as well as for total yields for the whole picking season.

The returns with picking costs deducted in dollars per acre as presented in Table I, demonstrate that Schedule 1 gave the highest

TABLE I—Effect of Frequency of Picking on Yields and Returns

Date	Yield (Tons Per Acre)						Returns* with Picking Costs Deducted (Dollars Per Acre)		
	U. S. No. 1's			No. 1's Plus No. 2's					
	Schedule 1	Schedule 2	Schedule 3	Schedule 1	Schedule 2	Schedule 3	Schedule 1	Schedule 2	Schedule 3
Sep 4	1.34	—	—	1.70	—	—	—	—	—
Sep 11	0.88	1.94	—	1.18	2.17	—	—	—	—
Sep 18	1.44	—	—	1.63	—	—	—	—	—
Sep 24	1.48	2.65	3.54	2.01	3.55	4.58	—	—	—
Totals to Sep 25	5.14	4.59	3.54	6.52	5.72	4.58	139.92	123.72	97.44
Oct 1	1.03	1.05	0.83	3.63	4.03	3.39	—	—	—
Oct 13	0.07	0.17	0.07	0.37	0.40	0.48	—	—	—
Grand totals	6.24	5.81	4.44	10.52	10.15	8.45	201.17	191.63	154.49

*Returns are calculated by taking 30 dollars a ton as the contract price for U. S. No. 1's, 18 dollars for No. 2's, and 6 dollars a ton as the cost of picking.

return, while Schedule 2 followed closely. Although the differences between Schedules 1 and 2 were almost negligible, the differences between these two and Schedule 3 were very great, and would be exceedingly important to the farmer.

Rather surprisingly the percentage of U. S. No. 1's was very nearly the same at each harvest regardless of the picking schedule followed.

Since the month of September was unusually dry, the 1947 season may have been exceptional. Further experimental work will be conducted to determine results under varying environmental conditions during successive years.

A Preliminary Report on the Effect of Various Cultural Practices with Greenhouse Tomatoes on the Respiration Rate of the Harvested Fruit

By E. K. Alban, H. W. Ford, and F. S. Howlett, *The Ohio State University, Columbus, Ohio, and The Ohio Agricultural Experiment Station, Wooster, Ohio*

The production of tomatoes in the greenhouse has been a major horticultural enterprise in Ohio for many years. Particular emphasis has been placed on increased yields and general quality aspects of tomato production in the research program in the past. In recent years, however, it has become increasingly apparent that there is a real need for fundamental research relative to the post-harvest handling of this crop.

In the spring of 1947, work was started at Columbus in an effort to determine the effect of various cultural practices on the keeping quality of tomatoes. The major approach to the problem involved the determination of the rate of respiration of the harvested fruit, since this has been shown to be one of the most valuable indices of the rate of breakdown of many fruits and vegetables.

Materials and Methods

The tomato fruits for these studies were obtained from previously established experimental plots at the University and the Experiment Station, and from certain commercial greenhouses in the northeastern part of the State. In this way uniform samples from tomato plants grown under a wide range of controlled conditions were obtained. A description of the plots included in this study appear under the appropriate headings in the presentation of results.

Fruits were harvested in the "pink stage" and comparable samples were held under uniform conditions throughout the period of study. Where fruits had to be stored for 3 to 6 days before testing, the storage temperature was 60 to 70 degrees F. All test runs involving the determination of the rate of respiration were made in a constant temperature storage (70 degrees F $\pm$ 1.5 degrees F). Six or eight fruits were used for each sample during a test run. It was found that 12 to 24 hours were required to obtain a uniform fruit and chamber temperature.

The equipment used for determining the rate of respiration was designed and constructed by the authors and is described in detail in another paper (1). This apparatus is essentially a modification of the Heinicke and Hoffman (2) system involving the absorption of carbon dioxide in towers containing a sodium hydroxide solution. Twelve separate units are operated at one time from a common air source. The apparatus operates as a pressure system on 4 pounds of air pressure at the scrub tower. After the air passes through the scrubbing tower, where all carbon dioxide is removed, it passes through a small distributing cylinder which provides an equal volume of air through each of the 12 chambers. One to 3 kilograms of produce can be convenient-

ly held in each chamber. The CO_2 — free air passing through these units then contains the CO_2 respired by the fruit sample during a particular test. The air-flow rate over each sample during an hour test can be varied between 2 to 4 cubic feet per hour. This rate can be controlled and is uniform for all 12 samples. The CO_2 is collected in the sodium hydroxide solution in an absorption tower for each sample. The normality of the sodium hydroxide solutions used in these studies was 0.05 N, or 0.1 N, but would vary with the kind or amount of produce and the length of a test run.

Results and Discussion

1. *The Rate of Respiration of Fruit Harvested from Tomato Plants Grown Under Three Night Temperature Conditions in the Greenhouse:* — In connection with certain blotchy-ripening studies of tomatoes at Columbus, three thermostatically controlled greenhouses were maintained at 57, 62, and 67 degrees F night temperatures for the fall crop, 1947. The day-time temperature of all three houses was approximately the same, 70 degrees F (except when outside temperatures were higher). The varieties Master Marglobe and Globe strain A were planted in the greenhouse in ground beds on July 25.

The fruits used in the respiration studies were harvested from the fifth, sixth, seventh, and eighth clusters. In most instances the flower and fruit development of these clusters occurred after the night temperature controls were most effective (after September 15). Fifteen to 20 pounds of fruit were harvested from each variety and for each night temperature at each harvest period. Eight fruits were selected from each lot, based on uniform size and maturity, and placed in the respiration units. Test runs were made within ½ hour after harvest, and at 24, 48, 72, 120, and 144 hours after harvest. The respiration rates listed in Table I are in most instances, the average of three separate runs.

TABLE I—The Effect of Night Temperatures on the Respiration Rate of Greenhouse Tomato Varieties, Master Marglobe and Globe Strain A (Respiration Rates Determined at 70 Degrees F and Expressed in Milligrams of CO_2 Per Kilogram of Fruit Per Hour)

Night Temperature (Degrees F)	Number Hours After Harvest					
	0	24	48	72	120	144
			Master Marglobe			
57	68.8	51.4	40.4	40.1	36.3	35.9
62	63.0	49.5	41.0	39.9	38.7	39.4
67	62.7	48.0	45.7	37.8	40.1	42.3
			Globe Strain A			
57	64.8	44.7	37.2	34.1	33.2	34.0
62	54.7	43.8	38.2	36.0	35.8	35.8
67	72.9	52.3	42.3	39.0	39.1	42.3

With the variety Globe, with but few exceptions, the rate of respiration was highest for the fruits from 67 degrees F; intermediate for fruits from 62 degrees F; and the lowest for the fruits from 57 degrees

F night temperature houses (Fig. 1). While this trend was less marked with the variety Master Marglobe (Fig. 2); respiration measurements made at the 120- and 144-hour post-harvest periods followed the same pattern as shown with the variety Globe. Most fruit samples at the end of the 144-hour period were too soft to be marketable but there was no correlation between night temperature and degree of fruit softening.

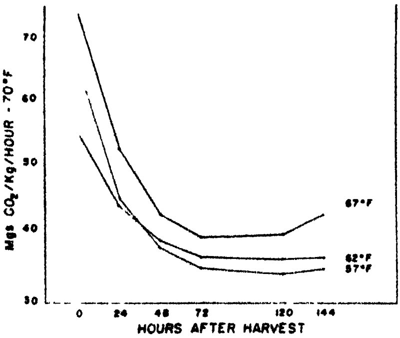


FIG. 1. The effect of three night temperature conditions with greenhouse tomatoes on the respiration rate of the harvested fruit (Variety Globe).

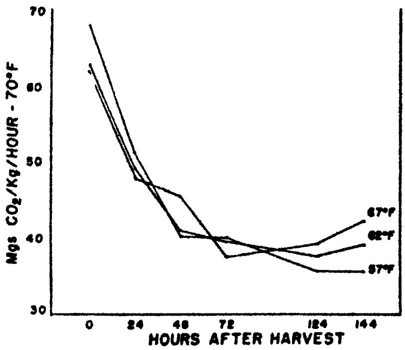


FIG. 2. The effect of three night temperature conditions with greenhouse tomatoes on the respiration rate of the harvested fruit (Variety Master Marglobe).

2. *The Effect of Various Concentrations and Combinations of Growth Regulating Chemicals, Used in Flower Treatments, on the Respiration Rate of the Harvested Fruit:* — The fruits used in this study were obtained from certain experimental plots at Wooster, Ohio. Aqueous solutions of beta-naphthoxyacetic acid, ortho-chlorophenoxyacetic acid, ortho-chlorophenoxypropionic acid, tri-chlorophenoxypropionic acid, and indolebutyric acid were used alone and in combinations as flower treatments. The variety Globe was the only one included in the study. In some instances the flowers were untreated, in others the electric vibrator pollinating method was used alone and in combination with one of the above chemicals, and in the fourth method the flowers were emasculated and then treated with one of the above chemicals.

There was no consistent difference in the rate of respiration of the fruits harvested from the treated or untreated flowers (Table II). There was apparently no correlation between the kind, amount, or combination of chemical used in flower treatments with the rate of respiration of the harvested fruit. Comparison of the fruits from emasculated-treated versus the pollinated-treated flowers revealed no major differences in the rate of respiration. Where comparable samples were held for varying periods, there was no indication of a more rapid breakdown of the treated fruits as compared with the untreated fruits.

TABLE II—THE EFFECT OF VARIOUS CONCENTRATIONS AND COMBINATIONS OF GROWTH REGULATING CHEMICALS, USED IN FLOWER TREATMENTS, ON THE RESPIRATION RATE OF THE HARVESTED FRUIT (THE DATE OF HARVEST, STORAGE CONDITIONS, AND THE DATE OF TEST RUNS ARE INCLUDED)*

Treatments	Harvest Date	Storage Days (60 to 70 Degrees F)	Respiration Rate (Mgs CO_2/Kg/Hour)		
	Oct 25	4	*Oct 29*	*Oct 30*	*Oct 31*
Untreated			38.4	33.4	36.7
Pollinated and 0.1% IB-10 ppm TCPPA			38.5	32.2	32.9
Pollinated and 0.2% IB-50 ppm BNOA			39.1	34.5	39.1
Pollinated and 50 ppm OCPPA			35.6	31.4	31.5
Pollinated and 25 ppm BNOA			35.1	30.7	29.7
Emasculated and 50 ppm BNOA			34.3	28.3	27.8
	Oct 31	5	*Nov 5*	*Nov 6*	*Nov 7*
Untreated			29.1	29.1	33.7
Pollinated and 25 ppm BNOA			31.1	31.7	36.0
Emasculated and 25 ppm BNOA			29.8	32.5	35.7
Pollinated and 50 ppm OCPPA			31.3	33.1	38.7
	Nov 14	3	*Nov 17*	*Nov 18*	*Nov 19*
Untreated			45.7	40.5	40.3
Pollinated and 25 ppm BNOA			44.8	41.4	38.4
Pollinated and 0.2% IB-25 ppm BNOA			43.3	39.1	35.7
Pollinated and 50 ppm OCPPA			47.6	45.8	40.6
Emasculated and 50 ppm OCPPA			54.0	51.5	44.7
Emasculated and 20 ppm TCPPA			55.8	52.4	46.9
	Nov 21	10	*Dec 1*	*Dec 3*	
Untreated			37.0	36.1	—
Pollinated and 50 ppm OCPAA			33.5	33.4	—
Pollinated and 50 ppm OCPPA			36.6	32.9	—
Emasculated and 50 ppm OCPPA			36.8	36.1	—
	Nov 28	6	*Dec 4*	*Dec 6*	*Dec 9*
Untreated			27.5	25.8	28.9
Pollinated and 50 ppm OCPPA			26.6	27.6	28.1
Pollinated and 50 ppm OCPAA			32.2	27.5	32.8
Pollinated and 0.2% IB-50 ppm BNOA			34.6	34.9	31.4
Pollinated and 20 ppm TCPPA			28.0	27.3	32.1
Emasculated and 20 ppm TCPPA			39.8	35.9	36.9
	Dec 5	7	*Dec 12*	*Dec 13*	*Dec 14*
Untreated			26.7	34.7	36.5
Pollinated and 20 ppm TCPPA			27.8	38.6	39.9
Pollinated and 50 ppm OCPPA			22.8	35.0	35.5

*IB indolebutyric acid; TCPPA tri-chlorophenoxyproprionic acid; BNOA beta-naphthoxyacetic acid; OCPPA ortho-chlorophenoxyproprionic acid; OCPAA ortho-chlorophenoxyacetic acid.

At the conclusion of the respiration measurements, the fruits in each sample were cut and graded on a basis of flesh and pulp color, degree of seedlessness, and general market desirability. There was some variation between the treatments in respect to the above factors. Under the conditions of this study, there were no consistent respiration differences which could be associated with any of the grades stated above. Comparison of the treated and untreated fruits indicated that the mechanical structure (degree of seed development and pulp fill) might offer a partial solution to the problem of premature softening of the treated fruits. However, other factors not yet determined are probably also responsible for the fruit-softening as well as the minimum differences in the rate of respiration.

3. *The Respiration Rate of Fruit Harvested From Tomato Plants Grown Under Various Soil Potassium Levels in the Greenhouse:* — The fruits for these studies were obtained from certain previously established fertilizer plots at Wooster, Ohio. These plots were on a Wooster silt loam and were designed to study the relationship be-

tween certain fertilizer practices and soil and plant analyses. The fruits were harvested in the pink stage approximately 3 days before being brought to Columbus, where respiration studies were made. Globe was the variety grown under the following potassium levels; plot 1 received 2,000 pounds of potassium (K_2SO_4) per acre, plus complete fertilizer, except K as noted; plot 2 received 1,000 pounds of K_2SO_4 per acre, plus complete fertilizer, except K as noted; plot 6 received a complete fertilizer with the exception of potassium. Visual potassium-deficiency symptoms were present in plot 6.

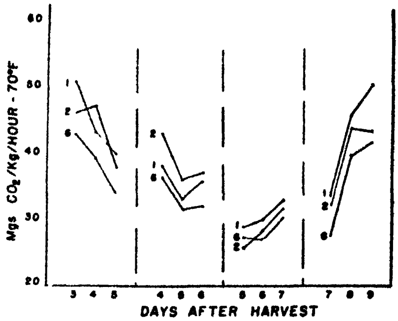


FIG. 3. The effect of three soil potassium levels with greenhouse tomatoes on the respiration rate of the harvested fruit. Variety Globe, plot 1 — 2,000 pounds K_2SO_4; plot 2 — 1,000 pounds K_2SO_4; plot 6 — no potassium added. All plots received complete fertilizer except potassium as above.

In each of the 20 tests, the rate of respiration of the fruits harvested from the minus potassium plot was lower than that of the fruit harvested from the plot where 2,000 pounds of K_2SO_4 per acre had been added. The mean difference was 5.8 mgs/kg/hour. In 16 out of 20 tests, the fruits harvested from the minus potassium plot had a lower rate of respiration than that of the fruits harvested from either the 1,000- or the 2,000-pound per acre K_2SO_4 application. The mean difference was 3.5 mgs/kg/hour. In 13 out of 20 tests, the fruits from the plot receiving 1,000 pounds K_2SO_4 had a lower rate of respiration than the fruits from the plot receiving 2,000 pounds of K_2SO_4 (acre basis). The mean difference was 2.1 mgs/kg/hour. From the above it is obvious that the potassium level affected the rate of respiration of the harvested fruit. Further studies are needed, however, before these effects of potassium on the keeping quality of greenhouse tomatoes can be more clearly evaluated.

SUMMARY

Certain preliminary results are presented on the effect of various cultural practices with greenhouse tomatoes on the respiration rate of the harvested fruit.

With the variety Globe strain A there was a trend for the fruits harvested from plants grown under 67 degrees F night temperature to have a higher rate of respiration than the fruits from plants grown under either 57 or 62 degrees F night temperature.

There was no significant difference in the rate of respiration of treated tomato fruits (growth regulating chemicals) as compared with the untreated fruits. Neither the method of treatment or the kind or combination of chemicals materially affected the respiration rate of the harvested fruit.

The respiration rate of the harvested fruit of greenhouse tomatoes grown under three soil levels of potassium revealed a positive correlation between high potassium level and high rate of respiration.

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The Effect of Holding Treatments Prior to Canning on the Vitamin Content and Palatability of Certain Vegetables

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Abstract

Complete reports of these investigations are being published in current numbers of *Food Technology* under the general title "The Nutritive Values of Canned Foods" (1).

Spinach, peas, green beans, lima beans, sweet corn, and carrots were held for varying periods of time and under different conditions of storage between time of harvesting and time of canning and the effects of the handling and holding procedures on the ascorbic acid, riboflavin, and thiamin content of both the raw and the canned products were determined.

In the case of peas, for example, three varieties were studied and the holding treatments for the shelled peas were as follows; prompt handling; storing in shade for 8 hours and 17 hours; washing to remove viner juice and then storing in shade for 8 and 17 hours; holding in running tap water for 18 hours; storage at 33 degrees F for 18, 48, and 96 hours; washing followed by storage at 33 degrees F for 18, 48, and 96 hours, and holding in snow ice in a room at 33 degrees F for 48 and 96 hours.

The temperature of lima beans held in lug boxes in the outdoor shade for 24 hours were 36 to 38 degrees F higher than the air temperatures due to biological activity in unwashed beans. Lima beans that were washed immediately after vining did not develop high temperatures when held at prevailing out-door shade temperatures or in cold storage. The results suggest the advisability of hydrocooling lima beans that are to be held as much as 12 hours after shelling. Unwashed, shelled peas did not "heat up" during holding periods.

The vitamin content of sweet corn was not affected appreciably by any of the storage treatments provided.

In general, the products that were processed as promptly as possible after harvest had the highest vitamin retention in both raw and canned products.

As the length of the holding period increased, the vitamin content tended to decrease. This was consistently the case with green beans held longer than 12 hours in the shade or longer than 48 hours in cold storage.

Cold storage usually resulted in better vitamin retention than holding at prevailing outdoor temperatures.

Washing of such products as lima beans and peas before subjecting them to the holding treatments was definitely beneficial but was of doubtful benefit to other commodities tested.

When such products as peas, lima beans, and green beans were held in tanks of running tap water, the ascorbic acid and thiamin contents

of both the raw products and the canned products were reduced, apparently by leaching.

The incorporation of snow ice with peas, lima beans, spinach, and green beans before placing in cold storage resulted in reduced ascorbic acid contents.

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Storage of Vine-Ripened Tomatoes[1]

By L. E. Scott and J. E. Hawes, *University of Maryland, College Park, Md.*

Recent developments in the packaging, transportation, and marketing of fresh fruits and vegetables have placed added emphasis on the importance of optimum maturity at time of harvest as a factor in quality of the consumer product. A large proportion of tomatoes available to the consumer have been harvested in the "green mature" stage and post-harvest ripened. The perishable nature of vine-ripened fruit has enforced this practice for growers distant from markets in spite of admittedly lower quality of tomatoes which have been harvested in the "green mature" stage. Furthermore, the advent of consumer packaging in retail tomato marketing has probably decreased the supply of vine-ripened tomatoes formerly available to the consumer through local growers.

The storage behavior of tomatoes harvested in the green mature stage has been investigated by a number of workers (1, 2, 5, 6, 7, 11), but comparable studies on fruit harvested at more advanced stages of maturity are limited (10). In connection with a project in progress on the handling of tomatoes for the fresh market, it was thought advisable to re-investigate certain factors in the storage of tomatoes, using fruit harvested after the inception of coloration.

Materials and Methods

Marglobe tomatoes harvested during September, 1947 from plots at the University research farm were used in all tests. The tomatoes after harvest were divided into three stages of maturity: Lot A, "pink" — fruits just pink at the blossom end, but entirely green around the stem; Lot B, "medium ripe" — fruits red at blossom end but still green around the stem; and Lot C, "ripe" — red coloration developing around stem but fruits still firm and not at canning ripe stage. An effort was made to secure uniformity of ripeness within each group. The tomatoes were placed in thermostatically controlled non-lighted constant temperature cabinets within 3 or 4 hours after harvest. Sample lots of four or five fruits from each of the three maturity lots were taken for color determination and organoleptic evaluation at stated intervals during storage.

The objective measurement of tomato color as developed by Kramer and Guyer (4) was used as an index of ripening. Their work shows the close correlation existing between visual evaluation and the objective measurement of color; and, in the present studies, the transmittance readings of a series of samples were found to be in accord with apparent surface color intensity as recorded with Kodachrome film. For the purposes of this paper increase in red color of the pulp as shown by the decrease in transmittance readings will be referred to as "ripening," although other factors involved in the ripening processes are recognized.

[1]Scientific Paper No. A204, Contribution No. 2121, of the Maryland Agricultural Experiment Station, Department of Horticulture.

Pie-shaped segments with a total weight of about 200 grams were blended in a Waring blendor to furnish the homogenous sample for extraction. Readings in Table I were obtained from duplicate segments from the same lot of four tomatoes and in Tables II and III from segments from duplicate lots of four tomatoes.

TABLE I—Ripening Rate of Tomatoes in Storage as Shown by Light Transmittance Values of Extracted Pigments (Read at 485 mu with a Beckman Spectrophotometer)

Stored at: (Degrees F)	Per Cent Transmittance at End of Storage Period of:						
	0 Days	2 Days	4 Days	7 Days	9 Days	11 Days	14 Days
	Lot A, Harvested "Pink"						
32	87.2	89.7	93.1	88 0	87.4	88.7	86 6
38	87.2	90.6	92.6	85 5	81.0	89.4	86 1
45	87.2	89.0	89.1	86 0	79.9	85.4	80.2
55	87.2	89.1	84.7	79.1	78.4	78.5	78.7
72	87.2	77.6	65.2	54.0	51 6	58.0	52.6
88	87.2	80.2	68.2	72.7	68.6	69.2	73.6
	Lot B, Harvested "Medium Ripe"						
32	84.6	88.1	88 3	85.2	83 9	87 0	84.6
38	84.6	85.7	87.8	83.4	83.0	84.8	85.3
45	84 6	86.1	84 0	83.8	79 5	84.3	77.6
55	84 6	86.0	83.8	83 7	81.5	84.1	77.8
72	84 6	69.0	56.9	52 1	51.0	54 1	48 4
88	84.6	77.2	66.6	63.5	61.2	68.0	64.9
	Lot C, Harvested "Ripe"						
32	77.0	82.2	81 0	80.5	73.6	81.0	80.9
38	77.0	78.8	78.0	80.6	79 6	82.5	82.8
45	77.0	81.4	68.0	82.5	76 6	78 5	79 5
55	77.0	76.0	77.9	79.6	77 6	79.8	78.8
72	77 0	72.1	58.0	53 2	44.5	53.2	49.6
88	77.0	65.5	59.0	56.0	60.3	61 9	69.6

TABLE II—Ripening of Tomatoes Held in Storage at 55, 60, 65, and 72 Degrees F for 9 Days (As Shown by Light Transmittance Values of Extracted Pigment Read at 485 mu with a Beckman Spectrophotometer)*

Stored 9 Days at: (Degrees F)	Initial	Per Cent Transmittance After 9 Days Storage
	Lot A, Harvested "Pink"	
55	85.6	79.6
60	85.6	64.5
65	85.6	60.0
72	85.6	55.8
	Lot B, Harvested "Medium Ripe"	
55	77.8	75.3
60	77.8	59.2
65	77.8	60.7
72	77.8	57.0
	Lot C, Harvested "Ripe"	
55	70.9	74.3
60	70.9	57.8
65	70.9	62.0
72	70.9	57.0

*The data represent means of analyses of duplicate samples of four fruits each. The standard error of the deviations between duplicate samples is 1.93.

TABLE III—EFFECT OF LOW TEMPERATURE STORAGE ON SUBSEQUENT RIPENING OF TOMATOES AT HIGHER TEMPERATURES (AS SHOWN BY LIGHT TRANSMITTANCE VALUES OF EXTRACTED PIGMENT READ AT 485 MU WITH A BECKMAN SPECTROPHOTOMETER)*

	Per Cent Transmittance at Indicated Period:		
	Harvested "Pink"	Harvested "Medium Ripe"	Harvested "Ripe"
Initial value:	90.6	85.5	79.2
Stored: (Days amd Temperature—Degrees F)			
6 at 32	90.6	85.3	78.1
12 at 32	93.0	89.7	78.6
17 at 32	89.7	88.0	80.5
5 at 72	65.0	55.1	53.0
6 at 32 + 5 days at 72	72.9	65.5	63.1
12 at 32 + 5 days at 72	80.9	63.7	69.8
5 at 85	69.2	68.0	60.0
6 at 32 + 5 days at 85	79.5	73.1	67.1
12 at 32 + 5 days at 85	81.2	66.5	69.7
6 at 50	87.1	81.5	72.7
12 at 50	83.1	80.5	74.2
17 at 50	78.9	74 7	71.6
5 at 72	65.0	55.1	53.0
6 at 50 + 5 days at 72	66.4	62.7	57 0
12 at 50 + 5 days at 72	63.7	76 8	60.8
5 at 85	69.2	68.0	60.0
6 at 50 + 5 days at 85	71.9	63.1	64.3
12 at 50 + 5 days at 85	66.5	76.2	66.5

*The data represent means of the analyses of duplicate samples of four fruits each. The standard error of the deviations between duplicate samples is 1.87.

RESULTS

Storage Temperature and Length of Storage Period:—Tomatoes harvested at the three stages of maturity; "pink", "medium ripe", and "ripe" were held at 32, 38, 45, 55, 72, and 88 degrees F storage. Samples were removed for color determination and organoleptic evaluation after 0, 2, 4, 7, 9, 11, and 14 days storage. The effect of temperature and duration of the storage period on the rate of ripening of the lots, as shown by the objective color measurements, is given in Table I. Maintenance of the initial transmittance values throughout the storage period indicate that little or no ripening occurred at 32 and 38 degrees storage. At 45 and 55 degrees storage there was still no perceptible change in the lot harvested at the "ripe" stage, but the two less mature lots exhibited definite but slow ripening at these temperatures. In all lots there was a decided change in behavior between 55 and 72 degrees F, with ripening taking place at a much greater pace at the latter temperature. The higher transmittance values maintained throughout storage at 88 degrees than at 72 degrees, is an additional demonstration of the inhibiting effect of high temperatures upon red color development in the tomato, a phenomenon reported in early work by Duggar (3) and later by Vogele (9) and Went *et al* (10). It is interesting in the present studies, however, that appreciable red coloration did occur at 88 degrees F (31.1 degrees C) in amount somewhat greater than at 55 degrees F storage, thus indicating the continued formation of lycopene at temperatures above 30 degrees C.

The failure of ripening to take place at the lower temperature range has been stated. Inspection of the data for the 32 and 38 degrees lots in Table I will show slightly higher transmittance readings after certain intervals of storage than the initial value. Although the significance of these differences is questionable, similar results from other experiments have indicated the possibility that actual loss of red color occurs at low temperature storage.

No decay or physiological breakdown was observed in the tomatoes held at the lower temperatures. The "pink" stage fruits became flat in taste and did not ripen sufficiently to be of acceptable edible quality after 14 days storage. The "medium ripe" and "ripe" lots were both acceptable after 14 days storage at 32, 38, 45, and 55 degrees; with perhaps the highest quality found in the ripe lots held at 32 or 38 degrees F. At 72 and 88 degrees F shriveling, decay, and off flavors were noted in all lots at the end of 7 days storage.

Comparison of transmittance readings with organoleptic evaluations of ripeness gave a division roughly as follows: (a) fruit giving transmittance readings above 80 per cent were definitely too green for eating, (b) fruit with readings from 80 to 60 per cent were in an edible stage of ripeness but were still solid and firm enough to withstand handling operations, and (c) fruit with readings of less than 60 per cent transmittance were in the soft ripe or "canning ripe" stage.

Critical Range of Ripening Temperature:—Since a great difference was observed between the ripening at 55 and 72 degrees F, a storage test was set up to more accurately define the temperature at which a sharp increase in rate of ripening occurs. Light transmittance readings at the beginning and end of a 9-day storage period, employing the three maturity lots held at 55, 60, 65 and 72 degrees F, are given in Table II. By far the greatest break in this series exists between 55 and 60 degrees F. In fact with the "medium ripe" and "ripe" lots, little difference in ripening was found from 60 to 72 degrees F.

Effect of Low Temperature Storage upon Subsequent Ripening at Higher Temperatures:—Deleterious effects of low temperature storage of green mature tomatoes upon removal to higher temperatures has been reported by several workers. Diehl (1) found storage at 32 degrees F for 8 days or longer resulted in collapse when removed to higher temperatures. Rosa (6) has given similar results with storage at 4 and 8 degrees C, and also showed retardation of subsequent ripening caused by low temperature storage. In the present studies an effort was made to ascertain whether these effects would likewise obtain with tomatoes harvested at more mature stages.

"Pink", "medium ripe", and "ripe" lots of tomatoes were stored at 32 and 50 degrees F for 6, 12, and 17 days; with samples removed at the end of 6 and 12 days to storage temperatures of 72 and 85 degrees F for 5 days. Transmittance readings for these lots are given in Table III.

The results are in agreement with the findings of Rosa (6) namely that storage at low temperatures retards the rate of color development exhibited at subsequent exposure to a higher temperature. Prolonging the low temperature storage period from 6 to 12 days increased the

amount of retardation. The retardation effect was more pronounced at 32 degrees F than at 50 degrees F, but was evident at the higher temperature. The retardation effects were similar with lots harvested at the different stages of ripeness. The higher readings obtained when the tomatoes were held at 85 rather than 72 degrees F again illustrates the inhibiting effect on coloration of the higher temperature.

None of the lots showed any evidence of breakdown or decay at the end of 6, 12, or 17 days storage at 32 or 50 degrees F. Some decay was noted, particularly in the "medium ripe" and "ripe" lots after the subsequent 5-day ripening period at 72 or 85 degrees F; but even then there was no evidence of a physiological breakdown or chilling injury caused by the 6 or 12 days storage at 32 degrees F. Storage at 32 degrees F for 6 days did not noticeably impair the flavor of the tomatoes after ripening at the higher temperature, but storage at this temperature for 12 days did cause the development of an off flavor after ripening at 72 or 85 degrees F.

Summary

The storage behavior of tomatoes harvested after red color development is initiated on the vine, apparently parallels in certain respects yet differs in others from that of fruits harvested at the green mature stage. The relationship between coloration and temperature is in general the same although it would seem that the reported complete inhibition (9) of red coloration effected by temperatures above 30 degrees C does not hold for fruits harvested after color initiation. The physiological collapse or breakdown described as occurring when green mature tomatoes are held at low temperatures before ripening was not found to occur in the present tests with vine-ripened fruit. The results obtained indicate the advisability of handling vine-ripened tomatoes under conditions of refrigeration (from 32 to 45 degrees F) in order to prevent loss from over ripening and to maintain highest quality. The present paper, however, has not considered the problems concerned with the production and transportation of vine-ripened tomatoes.

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Effect of Some Sodium Salts and Rate of Seeding on the Yield and Color of Beets

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ABSTRACT

This paper will be published in full in a bulletin of the New York State Agricultural Experiment Station.

THREE years experiments on all the important soil types commonly used for the commercial production of beets in New York proved that 500 pounds of common salt per acre or the equivalent amount of sodium in other sodium compounds would greatly stimulate the growth and profitably increase the yields of beets. But by the time these results were published the pricing system of beets for processing was drastically changed from a flat rate per ton to a graded basis in which only small beets brought attractive prices. This raised the question of whether any fertilizer treatment that stimulated the growth of beets would be profitable or merely increase the yield of large beets which would bring a smaller return.

This paper gives the results of 2 years experiments with increased rates of seeding beets grown with and without fertilizers and each of the following sodium salts: sodium chloride, sodium nitrate, sodium sulphate, and sodium carbonate. The largest net returns were obtained from the heaviest rate of seeding beets when grown on well fertilized land with the addition of sodium salts. The sodium not only increased the yield of roots but also produced a stronger top growth which was better adapted to machine harvesting which is essential for economical production. Increased rates of seeding did not increase the total yields per acre but significantly and profitably increased the production of small sized beets.

The beet plant is very sensitive to nutrient deficiencies and the foliage quickly shows typical symptoms of deficiencies. The "hunger signs" for nitrogen, phosphorus, sodium, and manganese are described and illustrated.

The Inheritance of Two Characters of Cucumis Melo and Their Interrelationship

By M. B. HUGHES, *Clemson Edisto Experiment Station, Blackville, S. C.*

THE Honey Dew melon has been used and probably will be used further in improving the quality of commercial cantaloupes as well as in developing adapted strains of the Honey Dew for the South. Hence, knowledge of the inheritance of two of its more obvious characters may be useful in future breeding work. Recently data have been obtained which indicate that the two pairs of allelic characters, dark versus white skin color and salmon versus green flesh color, exhibit simple Mendelian inheritance; also that the two pairs are inherited independently.

The Honey Dew melon, often referred to as the winter melon, *Cucumis melo* var. *inodorus,* to distinguish it from the common cantaloupe, var. *reticulatus,* is nevertheless of the same species and they cross readily. Because of its superior quality, Honey Dew and its derivatives have been frequently used to improve the quality of commercial cantaloupe varieties. Such varieties as Honey Ball, Weaver Special, Globe de Oro and Jade Beauty are obviously of such an origin. Besides these "white" varieties, both Honey Rock and V–1, Ferry Morse new sulphur-tolerant cantaloupe, have Honey Dew or one of its derivatives in their parentage.

Early lots of commercial seed of the variety V–1 gave a certain percentage of plants which produced white-skinned fruits. Observation of this character and its segregation aroused interest in its mode of inheritance. Accordingly, 13 V–1 plants, grown from commercial seed, were selfed. The fruits of all of these plants had the dark green skin, characteristic of most commercial varieties of cantaloupe. However, when these selfed lines were grown 12 of them bred true for the dark skin but one segregated eight dark fruited plants to five white. None of these lines was carried further except for one of the non-segregating dark fruited ones which continued to breed true.

From the same lot of commercial seed another dark-fruited V–1 plant was crossed with Smith's Perfect, also a dark-fruited variety. The F_1 plants were dark fruited but the F_2 segregated 89 dark to 36 white. This is a good fit for a 3:1 ratio, according to the chi square (X^2) test, as is the 8:5 ratio of the selfed V–1. It seemed likely, from this evidence, that the dark green skin of the commercial cantaloupe differed from the white skin of the Honey Dew and its derivatives with respect to a single dominant Mendelian factor. According to this supposition the V–1 plant whose selfed progeny showed segregation and the V–1 used for crossing with Smith's Perfect were heterozygous for the white gene. The F_1 plant selfed to obtain the F_2 received the white allele from its V–1 parent.

Seed from 37 selfed F_2 fruits was saved and 20 to 25 plants from each lot were grown the following year. Nine of these families were from white fruited plants and 28 were from dark fruited plants.

Of the nine F_2 families from white fruits, eight gave only white-fruited offspring. The other family, from which only four plants were obtained, gave three dark-fruited plants and one white. There are two possible explanations for this latter aberrant family. Either a contamination had occurred in pollinating or the F_2 fruit was misclassified. From the fact that frost had killed the F_2 plant before most of the seed was mature enough to be viable the latter explanation is the most likely. The fruit was undoubtedly small when classified and such an error could have occurred.

Of the 28 F_3 families grown from dark-fruited F_2 plants 18 segregated for white and 10 bred true. Since, theoretically, two-thirds of the dark fruited F_2 plants should have been heterozygous, the ratio of 18 to 10 is a good fit to the expected.

Table I shows the number of dark- and white-fruited F_3 plants of each of the 18 segregating families. In 16 of these there is a probability of 5 per cent or more that such an observed ratio would be drawn

TABLE I—MODE OF INHERITANCE OF DARK VERSUS WHITE SKIN IN CANTALOUPES

Cross	Observed		Calculated		X^2
	D	W	D	W	
Dark V-1 Selfed					
	8	5	9.75	3.25	1.255
Dark V-1 × Dark Smith's Perfect F_1 All Dark F_2					
	89	36	93.75	31.25	0.963
F_3 Families from Dark Fruited F_2's					
	18*	10**	18.67	9.33	0.072
Segregating F_3 Families from Dark F_2's					
29	13	4	12.75	4.25	0.020
30	17	2	14.25	4.75	2.12
34	19	1	15.00	5.00	4.27
35	16	6	16.50	5.50	0.060
38	17	5	16.50	5.50	0.060
40	11	10	15.75	5.25	5.73
41	16	6	16.50	5.50	0.060
44	20	4	18.00	6.00	0.89
45	13	5	13.50	4.50	0.073
Segregating F_3 Families from Dark F_2's—Concluded					
46	12	8	15.00	5.00	2.40
47	16	6	16.50	5.50	0.060
48	13	8	15.75	5.25	1.92
49	17	7	18.00	6.00	0.222
50	20	3	17.25	5.75	1.75
52	15	4	14.25	4.75	0.157
56	22	6	21.00	7.00	0.191
57	17	5	16.50	5.50	0.060
42	13	2	11.25	3.75	1.09
Total	287	92	284.25	94.75	
Total X^2	21.13 X^2 for 17 degrees freedom = 27.59				
Honey Dew × Smiths Perfect F_1 = Dark, F_2					
	88	25	84.75	28.25	0.496
Extra Early Hackensack × Honey Dew F_1 = Dark, F_2					
	122	36	118.5	39.5	0.413

*Segregating.
**Non-segregating.

X^2 for 1 degree of freedom
1 per cent = 6.035
5 per cent = 3.841

from a population existing in the ratio of 3:1. In the other two, the probability is between 1 and 5 per cent. If we assume that all 18 families were drawn from the same population and add the numbers of individuals of each family having the same skin color we get the segregation ratio of 287:92, almost a perfect 3:1. Although it is not permissible to take the X^2 of this total, since it is not known that all of the F_3 families were drawn from the same population, we can add the X^2's for the 18 families and compare it with the X^2 value at the 5 per cent level for 17 degrees of freedom. This gives 21.13, compared with a X^2 of 27.59 at the 5 per cent level. Thus these 18 families are in agreement with the theoretical 3:1 ratio.

Furthermore, in a cross of Honey Dew with Smiths' Perfect the

F_1 plants had dark fruit and the F_2 had 88 dark to 25 white-fruited plants. And in the cross of Extra Early Hackensack (dark-fruited) with Honey Dew the F_1 was dark-fruited and the F_2 segregated 122 dark to 36 white-fruited plants. Both of these ratios fit the theoretical 3 : 1 very closely.

Therefore, in spite of the single aberrant family of four plants mentioned earlier, it seems safe to conclude that dark skin differs from white skin in a single dominant allele.

In the Honey Dew — Smiths' Perfect cross there was another contrasting character pair of interest, green flesh versus salmon flesh. The F_1 were salmon fleshed. The F_2 segregated 63 salmon to 18 green. This is a good fit to a 3 : 1 ratio and suggests, although evidence is still insufficient, that salmon flesh differs from green with respect to a single Mendelian dominant.

Since both of the characters described above were present in the same cross it is interesting to see whether they are associated. Because Southern Blight (*Sclerotium rolfsii*) destroyed some fruits before flesh color notes were obtained, only 79 of the Honey Dew — Smiths' Perfect F_2 plants were classified for both characters. Table II shows

TABLE II—Mode of Inheritance of Salmon Versus Green Flesh in Cantaloupes

Observed		Calculated		X^2
S	G	S	G	
Honey Dew × Smiths Perfect F_2				
63	18	60.75	20.25	0.333

F_1 = Salmon X^2 at 5 per cent for one degree of freedom = 3.841

that 50 possessed both dominant characters, 15 were dark skinned with green flesh, 11 were white-skinned with salmon flesh and three had white skin with green flesh. Comparing this ratio with the 9 : 3 : 3 : 1 to be expected when two allelic series are segregating independently we find the observed ratio to be a good fit to the theoretical, that is — there is no evidence against the assumption that these two pairs of alleles are segregating independently of each other.

Mention should be made of two previous reports on the inheritance of skin and flesh color in cantaloupes. Lumsden (1) reports on a

TABLE III—Relationship Between Skin Color and Flesh Color in Cantaloupes

Observed				Calculated				X^2
Dark Skin, Salmon Flesh	Dark Skin, Green Flesh	White Skin, Salmon Flesh	White Skin, Green Flesh	Dark Skin, Salmon Flesh	Dark Skin, Green Flesh	White Skin, Salmon Flesh	White Skin, Green Flesh	
Honey Dew × Smiths Perfect F_2								
50	15	11	3	44.44	14.81	14.81	4.94	2.433

F_1 = Dark skin salmon flesh X^2 at 5 per cent for three degrees of freedom = 7.815

cantaloupe cross involving "yellow or straw-colored skin", Delices de la table, with Sutton's Superlative, a dark-green melon. Those F_1 plants which he considered true hybrids were yellow-skinned and the F_2 segregated 59 yellow to 21 green. Whether the white skin herein reported corresponds to the straw colored skin of Delices de table is unknown. It apparently differs from it genetically.

Hagiwara and Kamimura (2) working with Japanese varieties, report crossing a melon with "whitish-orange" flesh color with two white-fleshed varieties. They do not report the flesh color of the F_1 but it was apparently green or white. In the F_2 they got only five orange-fleshed individuals out of 348 in the one cross and only one out of 149 in the second cross. The description of the parental flesh color as whitish-orange suggests that it is an entirely different character from the salmon flesh described above.

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The Use of Naked Seed in Cucurbita pepo as a Source of High Quality Liquid Vegetable Fat, as a High Analysis Protein, as a New Confection, and as a Sandwich Spread

By Lawrence C. Curtis, *University of Connecticut, Storrs, Conn.*

Throughout history, such calamities as drought, plant disease epidemics, and war cause a dislocation in the production and distribution of food, and, as a result, people begin to look for new foods to supplement the insufficient supply. Today the urgent demand for more fats and proteins is apparent throughout the world. Are there plants, hitherto neglected, which may meet this growing need? More precisely, are there plants being used in some parts of the world which would prove valuable to the United States now or in the future?

The recent introduction of the soybean from China is an example of a successful importation which has become indispensable in our agricultural economy. Between 1920 and 1937 the acreage devoted to soybeans increased from 156,000 to 2,586,000; from 1937 to 1947 the acreage increased to the amazing proportions of 10,698,000 (1). And still the United States is short of fats and proteins. Is there possibly another oil bearing plant like the soybean waiting only for the proper introduction?

The seed of certain squash plants produces fat and protein which in the author's opinion should be investigated. The squash has been neglected in this country thus far, probably because no naked seeded types are grown here. But in Europe the naked squash seed has been used for an indefinite period of time; there are references indicating that it has been valued as an oil crop for more than 60 years. According to Jamieson (2) in 1932 squash seed oil was highly prized and was priced second only to olive oil. There are several references to the use of squash seed meal or pressed cake as a livestock concentrate (3).

The Russian scientist Pangalo in 1929 (4) reported that the fat content of many sample of squash seeds collected from various sources was about 45 per cent and that the Cucurbits would yield more oil per acre than flax, hemp, mustard, poppies and sunflowers.

In 1934 Dr. Erich Tschermak-Seysenegg (3) drew attention to the Styrian shell-less seeded (naked) type of pumpkin as a possible oil crop and declared that he intended to promote and publicize this pumpkin seed as a source of oil in the Netherlands and upper Austria. His program must have been fairly successful because, subsequently, several publications appeared in which plant breeding experiments as well as cultural practices of the pumpkin were described. World War II blotted out all scientific information about this crop, but letters and reports from agricultural representatives of both UNRRA and the UN state that in some sections of southeastern Europe pumpkin seeds constitute 25 per cent of the seeds sent to the local oil mills. In one letter this observation occurs: "The local Styrian forms are considered better (in oil, growth, yield) than the compact growing forms produced by Prof. V. Tschermak in Vienna" (3).

Why, then, since these countries have been making such large use of this naked pumpkin seed as a source of oil, has the United States neglected this crop? Perhaps because our needs for edible oils and fats, before the last war, were supplied by cotton seed, corn, peanuts, and soybean. In fact, we had enough for export. Today with our food shortages we need to look at this plant more closely.

At this point the question might arise: Why is a naked seed more desirable as a source of oil than the normal type? (a) Since the shell constitutes 25 to 50 per cent of the weight of the seed, the percentage of oil is correspondingly low. (b) During the process of pressing out oil from normal seeds, the hulls absorb part of the oil — thus reducing the yield of oil.

Squash seeds with their normal seed coats have been used as food in this country. Our literature is rich in references to use of Cucurbit seeds as a source of food. The natives of America ate these seeds as we do peanuts and ground them into a meal which they used for baking or gruel (5).

Nor has the naked seeded squash been unknown in this country. Several Experiment Station workers as well as seedsmen (6) have attempted to grow various naked seeded types which were imported from the Balkan countries; but they came to the conclusion that the project was not feasible for several reasons, (a) being naked, the seed rotted in the ground; (b) difficulties of properly extracting and curing the seed; and (c) low yield of seed per acre.

Through a breeding program carried on for the past 7 years at the Connecticut and Storrs Agricultural Experiment Station, these major obstacles have been overcome: (a) through the use of fungicidal protectants, the naked seed germinates as well as normal seed; (b) by the proper use of dryers and agitators the seed can be properly cured; and (c) by selection and hybridization the yield of seed has been increased tremendously as indicated in Table I.

TABLE I—The Yield of Seed Per Acre of 56 Lines of Naked Seeded Squash

No. of Lines	Range (Pounds of Seed Per Acre)	No. of Lines	Range (Pounds of Seed Per Acre)
Yields of Seed When the Breeding Program was Initiated		*Yields of Improved Lines*	
4	150–300	9	600–750
5	300–450	11	750–900
7	450–600	6	900–1050
		6	1050–1200
		2	1200–1400

There is no indication thus far that the limit in yield of seed per acre has been reached.

Now that the yield of squash seed per acre has been increased, how does it compare with the other oil bearing plants? Table II provides this information.

Aside from oil, naked squash seed is rich in protein and, as can be seen in Table II, compares favorably with the other oil bearing plants from which protein concentrates are derived.

Quite apart from the nutritive values of the squash seed, it is a tempting delicacy in its own right. The Indians knew that. Carter (5) suggests that perhaps it was the seeds of the Cucurbits which first attracted the attention of the botanical pragmatists among the American Indians.

TABLE II—YIELD PER ACRE AND PARTIAL COMPOSITION OF SEVERAL IMPORTANT OIL BEARING SEEDS AS COMPARED WITH NAKED SQUASH SEED

Crop	Approximate Range of Seed Per Acre	Per Cent Fat	Per Cent Protein	Per Cent Carbohydrate	Per Cent Fiber
Cotton seed	300-1000	23	19	21	17
Soybeans	1200-1800	17	37	26	4.5
Shelled peanuts	500-1500	48	31	12	2.5
Naked squash seed	500-1400	46	34	10	2.3

Roasted squash seeds are sold in the streets of Latin America for eating out of hand and the decorticated seeds, produced by cracking the seeds between the teeth and ejecting the hull, are used as nuts in the production of candies and pastries. In the United States 8 million pounds, much of which is imported from Mexico, are processed for the confection trade; that is, coffee cake covering or substitute almond paste. Some of the seeds are distributed to what is called the "crack and spit" trade.

These squash seeds, in spite of their shells, have had a continuous sale. Now that a naked seeded type is available, the possibilities of its increasing popularity as a confection seem assured.

Plain and in the raw, naked seeds have a bland flavor — like almonds; but roasted in deep fat, they become something new and strange. In the heat the seeds expand to several times their original volume and become circular in cross section. Salted, they taste like peanuts, but they are lighter, crisper, more subtle in flavor.

Other uses for this seed have been suggested. As a sandwich spread, in the opinion of many samplers, it surpasses peanut butter. The oil expressed from the de-endospermized seed is a clear straw color. As a base for mayonnaise, French dressing, or deep fat frying it has been found by chefs and cooks to be not only satisfactory but preferable to other vegetable oils. In a recent communication I am told that it is suitable for the production of margarine.

Surely the naked seeded squash has many desirable attributes to recommend it as a new crop. Such prosaic problems as increasing the yields, adaptation of the plant to varying climatic and soil conditions throughout the United States, improvement of the mechanical methods of harvesting must be met; but the rewards should amply repay the effort.

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Onion Curing — A Comparison of Storage Losses From Artificial, Field, and Non-Cured Onions[1]

By Burton J. Hoyle, *University of California, Davis, Calif.*

The method by which onions are cured can have an important effect on storage losses. The experiments reported in this paper were designed to compare storage losses after an artificial curing, a field curing, and a non-curing treatment.

Curing is a drying process. The field curing method takes several days to a few weeks depending on the time of year and geographical location. Where it is desirable to market onions quickly after harvest, a long curing period can be a decided disadvantage. The purpose of this paper is to present a method of rapid "artificial curing" which would overcome the disadvantages of a protracted curing period and to compare the storage results with the two other treatments mentioned above.

The removal of some moisture from onions to improve their keeping quality seems desirable since decay organisms are generally dependent upon moisture to survive. Walker (5) has pointed out that "prevailing rainy weather at harvest time will almost invariably lead to heavy losses. The moisture is favorable for the development of the fungi and bacteria." Also, "...high humidity of the atmosphere during the curing period causes the moisture given off by the onions to accumulate in the crate, which favors the development of decay". It follows that onions should be well cured, before they are placed in storage, and then kept dry. That the curing method can have a marked effect on the subsequent storage quality of onions was shown by Colby, Gilgut and Yegian (1) who found that field curing in piled crates was superior to both field curing in single burlap bags and curing in field windrows.

The artificial curing method described in this paper required a blast of heated air. Onion bulbs can be subjected to relatively high temperatures as has been shown by Murphy and McKay (3) who controlled downy mildew infection of onion bulbs by heating to 104 degrees F for 8 to 10 hours without injuring the bulbs. Yarwood (6) controlled downy mildew on growing onion plants by placing them at a temperature of 110 degrees F for 4 to 6 hours. Smith, Altstatt and Byrom (4) successfully cured garlic by placing it at 120 degrees F for 20 to 30 hours, but found that 125 degrees F would cause injury. I observed injury on onion bulbs held at 122 degrees F for 3 hours but 115 degrees F to 120 degrees F could be safely used for a considerable period of time.

Materials and Methods

Curing in burlap bags and in field windrows are the usual methods of curing onions in this section of California. Since curing in bags is generally considered superior to field windrows, bag curing was used to

[1]This work was supported in part by a grant from the Basic Vegetable Products Company, Vacaville, California.

compare with the artificial curing and non-curing treatment. All of the experiments herein described were conducted at the University Farm at Davis, California. Following curing, all onions were held in a common insulated storage in which the ventilators were opened at night and closed during the day. Although continuous storage temperatures were not recorded, limited records indicated that the maximum temperatures were on the average 7 degrees F cooler and the minimum temperatures were 14 degrees F warmer than the corresponding outside temperature. Thus the outside temperatures would indicate that the minimum storage temperatures usually fell between 60 and 75 degrees F, and the maximum storage temperatures between 70 and 90 degrees F.

The curing process described here as "artificial curing" consisted essentially of forcing a draft of heated air through bagged onions long enough to partially dry them. Only onions in open mesh bags were cured on this dryer. The design of the artificial dryer was adapted from that of a sacked grain dryer (2). Fig. 1 shows the onion dryer in

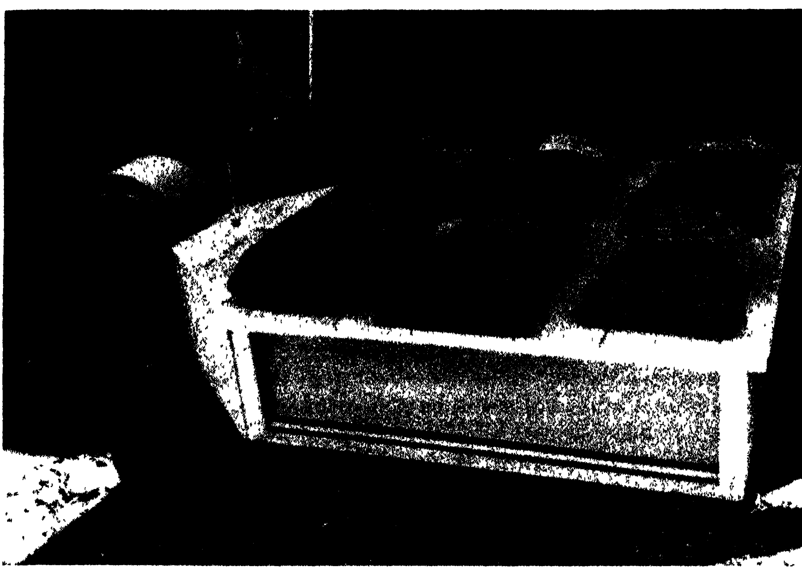

FIG. 1. View showing onion dryer in operation with 50-pound bags of onions in place.

operation. The dryer accommodates six 50-pound bags of onions at one time. The fan used forced 50 cubic feet of air per minute through each hole and a horizontally-fired natural gas burner furnished the heat. During use the air blast temperature was kept as close to 115 degrees F as possible. The onions showed no injury at this temperature even after 16 hours.

In each of the three separate experiments conducted two or more of the following treatments were used.

I. Bulbs only used. Placed in storage in open mesh bags without curing. Hereafter this treatment is referred to as "no curing".
II. Bulbs only used. Cured in burlap bags in field. After curing, the bulbs were transferred to open mesh bags and placed in storage. Called hereafter "field curing".
III. Bulbs only used. Artificially cured as described above and placed in storage. Called hereafter "artificial curing".
IV. Bulbs plus 2 pounds of separate green tops added, no curing.
V. Bulbs plus 2 pounds of separate green tops added, field curing.
VI. Bulbs plus 2 pounds of separate green tops added, artificial curing.

With most methods of topping and bagging few green tops are mixed with the bulbs. However, a new lifting, topping and bagging machine being used will occasionally gets chunks of green tops into the bags. It was for this reason that green tops were added to some of the above treatments. It was also desired that the artificial dryer be put to as severe a test as it was probable it would meet. Further information pertaining to experiments A, B, and C is presented as follows.

For experiment A, Early Grano bulbs grown as transplants at Shafter and set out at Davis on January 20, 1946 were used. On June 10 they were harvested, and two open-mesh bags were filled with 40 pounds of bulbs badly damaged by a mechanical digger. In addition each bag had 2 pounds of fresh green tops mixed throughout. One bag was given treatment IV and the other treatment VI. This experiment was run primarily as a test of the feasibility of the artificial curing method.

For experiment B, Early Grano bulbs from the same field as those in experiment A were used. Only sound bulbs harvested by hand were used. These were harvested when 40 per cent of their tops were down and topped leaving necks ranging from 0 to 2 inches. Treatments I, II, and III were given with four bags of 40 pounds each used per treatment.

For experiment C, Southport White Globe bulbs planted from seed at Davis on January 15, 1946 and harvested August 1, when 40 per cent of their tops were down, were used. These were topped to 2-inch necks and only sound bulbs included; 45 pounds of bulbs were placed in each bag and three bags used per treatment. Treatments I through VI were used. For obtaining rot losses in all treatments the decayed bulbs were removed after 1 month and the percentage loss calculated on the fresh weight basis of 45 pounds. For obtaining weight loss records of treatments I, II, and III, the weight loss between the initial 45 pounds and the final weight before the rots were discarded was calculated as a percentage loss. This method of calculating weight loss must be kept in mind in using Table I and III, where it is evident that in the last three columns the figures for "rot loss" also include their weight loss. The figures for "weight loss" include the weight loss of the entire sample, or for both the rotten and sound bulbs. It is apparent then, that the weight loss of the rotted bulbs is included twice. Thus, when "weight loss" and "rot loss" are added and the total subtracted from 100 the figure obtained would be lower than the

actual "per cent usable left", indicated in the last column. In Table II "weight loss" and "rot loss" were calculated independent of each other and are, therefore, additive. Since for treatments IV, V, and VI the tops had disintegrated and in some cases turned slimy they could not be accurately separated and weighed. The weight loss for these treatments were calculated as a percentage of the original bulbs plus tops, or 47 pounds instead of 45 pounds.

Results

Experiment A:—The bag receiving the artificial curing (treatment VI) was placed on the dryer and turned occasionally for 8 hours during which time the temperature of the air blast fluctuated between 110 and 118 degrees F. This bag lost 7.6 per cent of its weight in this time. It was then placed in the onion bulb storagehouse beside the bag receiving no curing (treatment IV). The total percentage loss after 1 month in storage, as shown in Table I, was 38.2 per cent for the artificial curing and 91.4 per cent for the no curing treatment.

TABLE I—Percentage Weight, Percentage Rot Loss, and Percentage Usable Bulbs Left in Two Bags of Early Grano Onions, in Very Poor Condition From Mechanical Harvesting and With Separate Green Tops Added, After One Month Storage (June 11 to July 12, 1946)

Treatment	Weight Loss (Per Cent)	Rot Loss (Per Cent)	Usable Remainder (Per Cent)
VI Artificial curing	9.2	32.0	61.8
IV No curing	17.8	89.5	8.6

Experiment B:—The results of this experiment with Early Grano bulbs are shown in Table II for approximately 1, 2 and 3 months of storage. At the end of 1 month the treatment receiving no curing was rotted so badly it had to be discarded. The other two treatments, field curing and artificial curing, showed no significant differences in any of the losses for any of the periods. However, in appearance the artificial curing treatment was superior to the field cure.

TABLE II—Weight Loss, Rot Loss, and Usable Left in Percentage of Original Weight of Sound Early Grano Onion Bulbs for Three Periods (All Percentages Are Averages of Four Bags)

Treatment	Jun 11 to Jul 12			Jun 11 to Aug 13			Jun 11 to Sep 3		
	Wt Loss (Per Cent)	Rot Loss (Per Cent)	Usable Left (Per Cent)	Wt Loss (Per Cent)	Rot Loss (Per Cent)	Usable Left (Per Cent)	Wt Loss (Per Cent)	Rot Loss (Per Cent)	Usable Left (Per Cent)
I No curing	11.8	76.7	12.5	—	—	—	—	—	—
II Field curing	6 1	20.0	73.9	11.2	23.3	65.5	14.5	36.7	48.8
III Artificial curing	6.3	12.3	81.4	10.8	16.3	72.9	13.2	24.8	68.0
Difference required for odds 19:1	3.3	14.9	—	No significant difference					

Experiment C:—Data taken on the percentage weight loss, rot loss, and good bulbs left at the end of the curing period and 1 month later are shown in Table III. Fig. 2 shows good bulbs and discards after

1 month in storage for representative lots from the six treatments. The length of curing and the average temperature for each of the treatments used was as follows:

Treatment	Method of Curing	Length of Curing	Usual Range of Warmest Temperature During Curing (Degrees F)
I	None	0	———
II	Burlap bags in field	8 days	70 to 85
III	Artificial curing	13 hours	105 to 118
IV	None	0	———
V	Burlap bags in field	8 days	70 to 85
VI	Artificial curing	16 hours	105 to 118

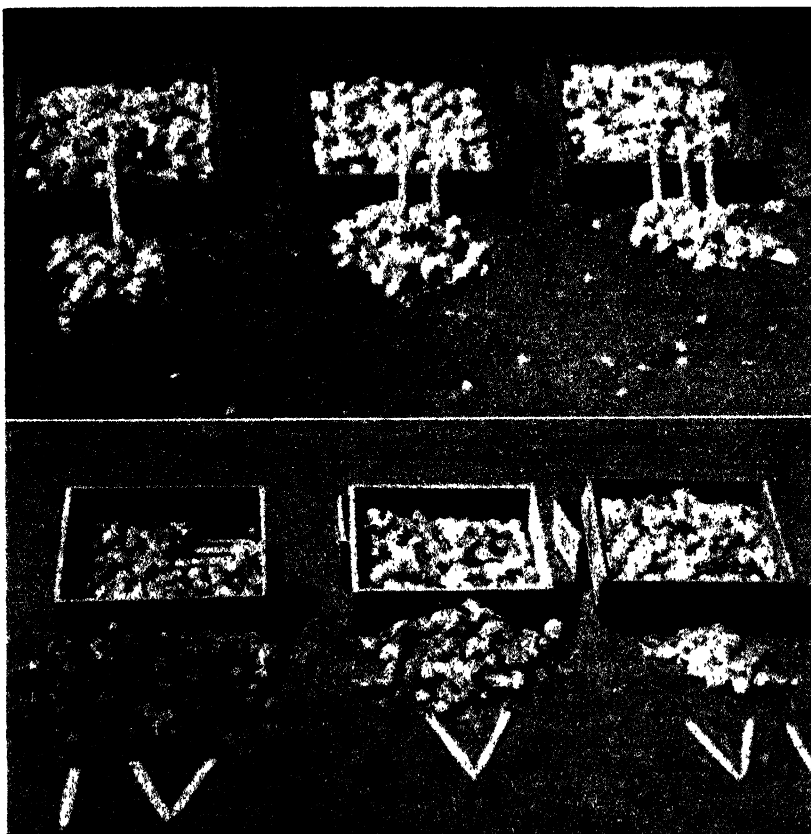

FIG. 2. Representative lots of six treatments of Southport White Globe onions (Experiment C) after curing and storage of 1 month, (August 1 to September 1, 1946). The rots are piled in front of each crate from which they were separated. The treatments were as follows:

I. Bulbs only, no curing.
II. Bulbs only, field curing.
III. Bulbs only, artificial curing.
IV. Bulbs with loose green tops added, no curing.
V. Bulbs with loose green tops added, field curing.
VI. Bulbs with loose green tops added, artificial curing.

From Table III the following observations can be made for the immediate effect of curing. (a) Weight losses for bags containing only bulbs were lower than those treatments having green tops mixed in. (b) The weight losses were lower for bulbs artificially cured than for the field curing.

TABLE III—Weight and Rot Loss, and Usable Southport White Globe Onions Left Expressed in Percentage of Original Bulb Weight After Curing and After One Month Storage (Aug. 1 to Sept. 1) (Percentages Are Averages of Three Bags)

Treatment	At End of Curing Period			After One Month Storage Including Curing		
	Weight Loss (Per Cent)	Rot Loss (Per Cent)	Usable Left (Per Cent)	Weight Loss (Per Cent)	Rot Loss (Per Cent)	Usable Left (Per Cent)
I. No curing, bulbs alone	—	—	—	7.7	20.5	73.3
II. Field curing, bulbs alone	5.1	0	94.9	9.6	36.1	57.8
III. Artificial curing, bulbs alone	2.7	0	97.3	9.2	15.4	76.8
IV. No curing, bulbs plus loose tops	—	—	—	15.3*	80.0	19.2
V. Field curing, bulbs plus loose tops	5.8	0	84.2	14.8*	42.5	52.4
VI. Artificial curing, bulbs plus loose tops	4.3	0	95.7	10.8*	9.0	84.9
Difference required for odds 19:1	0.7	—	0.7	1.7	11.0	10.5
99:1	—	—	—	2.4	15.2	14.5

*Based on total weight loss of bulbs and tops.

Observations on weight losses after the 1 month storage period showed: (a) Differences in weight loss were not significant between the two lots receiving artificial curing (treatments III, VI), but these two treatments showed less weight loss than all others except no curing. (b) The two field curings (treatments II and V) showed higher losses than the no curing (treatment I) for bulbs alone. (c) The highest losses were for no curing (treatment IV) and field curing (treatment V).

The treatments in order of least rots to most rots after a month were:

VI. Artificial curing, bulbs plus tops
III. Artificial curing, bulbs alone
I. No curing, bulbs alone
II. Field curing, bulbs alone
V. Field curing, bulbs plus tops
IV. No curing, bulbs plus tops

Treatment VI was significantly better than all the rest except III, while III was significantly better than all others except VI and I.

The treatment having the most usable bulbs remaining after one month was the same as the one having the least rots. The treatments listed in order of most usable bulbs to least usable bulbs left for this period are, VI, III, I, II, V, and IV. Treatment VI had significantly fewer losses than all the others except III, while III showed significantly fewer losses than all except VI and I.

Discussion

The results presented show that artificial curing was a fast and safe method of curing onions. Besides drying the bulbs and eliminating moisture the temperature used was high enough and maintained long enough to kill any downy mildew infection according to the results shown by Yarwood (6), and Murphy and McKay (3).

In calculating weight loss of the bulbs alone in treatments having green tops mixed throughout the bulbs, one would need to know the actual weight loss of the tops. This was not possible to obtain accurately due to the condition of the tops at the end of the storage period. In general, the tops in the treatments given the artificial curing were quite dry and brittle, the tops in the lots receiving field curing were partly dry and partly limp and moist, while the tops of those not cured were quite moist, slimy and black.

Field curing in burlap bags is often practiced by growers. That this method may not be entirely satisfactory even for ideal western conditions is indicated in experiment C. Colby, Gilgut, and Yegian (1) have shown that for the usually less ideal eastern curing conditions field curing in burlap bags was not generally satisfactory. In both cases poor circulation of air through the bags, allowing for accumulation of moisture, is probably a contributing factor. It will be noted that in Tables I and II the "no curing" treatment was followed by a rapid breakdown in storage. However, in Table III it can be seen that the "no curing" treatment was one of the best keeping lots. This apparent discrepancy is hard to explain but may be due in part to varietal difference and in part to the time of year; that is, the general climatic conditions may have been more favorable during August than during June and July.

The artificial curing equipment used and described in this paper, accommodated only six bags of onions at one time. Curing equipment could be built which would handle many more than this. Sacked grain artificial curing tunnels have been designed to dry 1000 sacks of grain at one time.

Summary

Onion bulbs cured artificially by forcing warm air, at 105 to 118 degrees F, through open mesh bags containing the bulbs was compared to onions both cured in the field in burlap bags and to onions placed directly in storage after harvesting and topping. The following observations were made on the relative keeping qualities of the onions receiving the various treatments.

1. Moisture loss was greatest in treatments where rotting was severe.
2. Field curing in burlap bags was, in general unsatisfactory.
3. For storage, onions should be free as possible from bruises, cuts, and green material.
4. Bulbs with green material mixed among them stored well after artificial curing, but quickly decayed if field cured or not cured.
5. In all the experiments conducted the artificial curing saved much time and was highly satisfactory.

6. No bulbs showed heat injury from the artificial curing which in general took 16 hours in an air blast of 105 to 118 degrees F.

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Color Specification of the Federal Canning Tomato Grade as Related to Horticultural Color Determination[1]

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One of the most generally used standards for grading the quality of fresh fruits and vegetables are those developed by the federal government. The canning tomato standards have been in use since 1926. These standards have two classes of color differentiations for canning tomatoes, namely "well colored" and "fairly well colored". These same color terms also have been used in areas which are not using the federal grades in their entirety. There is reason to believe that as much as 60 per cent of the canning tomatoes purchased in the United States in recent years have been graded according to these two terms.

The official grades indicate that a well-colored tomato means that at least 90 per cent of the flesh has a good red color (U. S. No. 1); likewise, a fairly well colored tomato indicates that at least two-thirds of the flesh of the tomato has a good red color (U. S. No. 2). The federal canned-food grades indicate the importance of color as a quality characteristic. With the development of a method for measuring tomato color (21) it then seemed desirable to attempt to define these minimum colors in terms of color attributes. Such studies were made in Indiana in 1931 and 1932, and in California in 1942 and 1943.

Color is an important factor in connection with the quality of horticultural crops. Considerable research has been reported on the subject, but it is well to remember that color is considered from many different viewpoints — by the chemist, the physicist, the physiologist, or psychologist, and by the man of the street. The chemist is usually interested in the quantity of pigments, dyes, etcetera. The physicist expresses color in terms of stimuli or the relative amount of reflection or transmission at different wave lengths of light. The psychologist measures the sensation of color. The last two procedures may be used to express data in color attributes — a term meaning a psychological expression of color. These various points of view may cause confusion, particularly if they are used indiscriminately.

The following pairs of terms or color attributes are synonymous in expressing color: dominant wave length and hue; relative brightness and value; and purity and chroma. "Hue (46) is that attribute of certain colors in respect of which they differ characteristically from the gray of the same value and which permits them to be classed as reddish, yellowish, greenish or bluish. Brilliance (value) is that attribute of any color in respect of which it may be classed as equivalent to some member of a series of grays ranging between black and white. Saturation (chroma) is that attribute of all colors possessing a hue, which determines their degree of difference from a gray of the same value (dull versus bright color)".

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Since color is an important consideration in the quality of many horticultural crops, it seemed desirable to give a complete review of this literature. The methods of color determination have varied greatly with different crops and many of the papers are of a preliminary nature but nevertheless have been included. The following papers have been classified according to three methods of measuring color: (a) by spectrophotometer, in some cases with the specification of the color in color attributes; (b) by Munsell color notation expressed in color attributes; and (c) where the pigment or pigments were extracted for measurement, by empirical scale on which colorimetric data were expressed, or merely by observations and comparisons with the unaided eye.

General Review of Literature as Related to Horticultural Color Problems

Spectrophotometric Data:—The spectrophotometer has been used to study the appearance of several agricultural products. Some workers report only reflection or transmission curves, and others describe the appearance of the product in color attributes. Fischbach and Newburger (12) made a study of canned peas, prepared by various processes, to determine the most desirable shade of green. The same authors (11) also made a study of canned okra. In both instances, they report only reflection curves.

Stephens, Child, and Bailey (44) studied the effect of different grades of molasses, different amounts of sodium bicarbonate, and baking time and temperature on the color of cookies. They were primarily interested in the lightness of the cookies, and did not report their reflection curves in terms of color attributes. Data are summarized on the basis of percentage reflection at one wave length.

The spectral curves of several varieties of apples separated as to skin, flesh, and maturity are reported by Lott (19, 20). These curves indicate varying amounts of reflection, and the author suggests the use of the spectrophotometer for determining maturity standards of apples.

McCollum (26) reports curves obtained on samples of tomato juice varying in color. When these values are converted to dominant wave length (hue) and purity (chroma), the differences in color attributes are rather small. Extraction of these samples for total lycopin pigment gave appreciable differences in the amount of pigment.

For several years, it has been known that tomatoes do not redden normally when ripened above 85 degrees F. Vogel (47) has extended our knowledge on this subject by measuring the color changes. His work contains reflection curves and also color attributes. Vogel's data show that dominant wave length becomes less red from 24 to 28 degrees C, then becomes a markedly poorer red at higher temperatures. Purity, however, improves with a temperature up to about 32 degrees C, but this attribute becomes some poorer above this temperature. As indicated by dominant wave length, ethylene treatment tends to improve the color up to a temperature of 36 degrees C.

Winkler and Amerine (49) have studied the color change in wine

resulting from a change in pH. An increase or a decrease in hydrogen ion concentrated produced a wine slightly less red in hue but also slightly brighter.

Compton, Granville, Boynton, and Phillips (8), have suggested the use of leaf color of McIntosh apples as a means of determining the nitrogen content of the leaves. Reflection curves as well as Munsell notations were made of the leaves. Color of the selected samples was recorded from both data. If color is expressed in terms of color attributes, there not only seems to be a variable difference in color between samples, but these differences are not consistent when the two procedures are compared.

MacGillivray (25) determined the spectrophotometer curves for samples of tomato pulp differing in color through use of a hand-operated spectrophotometer. He also published reflection curves for similar data obtained with a recording color analyzer. The first data were expressed in color attributes without too good an agreement between color sensation recorded by the physical method and that recorded by the Munsell procedure. Three of the preceding papers used both physical and psychological methods to determine color of their samples.

Munsell Color Determinations: — A considerable number of research workers have made use of Munsell color measurements to describe colors. Nickerson (35) was one of the first workers to use this procedure in relation to agricultural problems. Much of her work has been with grades used for agricultural crops and products. Both stimulus and sensation measurements were considered in measuring color of grades of cotton and later grades of such hays as alfalfa, clover, Johnson grass, and Prairie hay. This work has been extended to include samples of canned vegetables, such as tomatoes, tomato pulp, canned corn, as well as grains and bread. Following these original studies there was a more general use of the Munsell method of color measurement.

MacGillivray (21, 22, 23, 24, 25) and Gaylord and MacGillivray (13, 14, 15) have published several papers on color determinations of tomatoes, particularly in relation to the canning industry. Munsell color determinations (21) were first used to determine the color of the different regions of a tomato fruit. The wall tissue was found to be both redder and brighter than the tissue around the seeds.

In 1933, Shrader and Beaumont (40) made use of Munsell color measurements to determine the effect of nitrogen fertilizer on the color of Stayman apples. These exhibited considerable range in hue and chroma.

As federal grades were used more commonly for the purchase of canning tomatoes, it became desirable to record the color of U. S. No. 1's, U. S. No. 2's, and culls (Gaylord and MacGillivray 13). The Indiana data and other unpublished results indicate that the color rating of U. S. No. 1's is about 7.8, and of U. S. No. 2's is considerably poorer in color, or 11.1. Other work indicated a somewhat better color for U. S. No. 2's. Both the processed and the fresh tomatoes were used for further color studies (22). This bulletin covers the general

aspects of color determination, and also calls attention to the fact that sterilization causes impairment of tomato color. There seems to be a rather good correlation between the percentage of U. S. No. 1's delivered by the growers and the color of the canned pulp.

A considerable number of the previous experiments were duplicated by Taxner (45) working in Hungary. Munsell color determinations were made on tomatoes of different degrees of ripeness, grown on different soil types. Determinations were also made on the color of different purees. His results, particularly on processing, seem quite similar to data reported by MacGillivray (22). Since processing temperatures caused an impairment of color, a further study (MacGillivray 23, Taxner 45) was made of the effect of different temperatures without regard to keeping quality of the canned product. When juice was held the same period at different temperatures there was the least color change at low temperatures, with progressively greater impairment at higher temperatures. When oxygen gas was passed through the juice, the color change was increased. The color change from heating good colored juice was greater than from heating poor colored juice, but this change was not great enough to reverse the final colors. However, the difference in color of the two samples of raw juice was much greater than that of the heated juice.

MacGillivray (24) next reported a study of the lycopin crystals as well as on the carotin or yellow pigment of good and poor juice. Heating caused a decrease in the size of lycopin crystals, but also caused a clumping of the yellow pigments. The resulting impairment of color is thought to be due as much to the yellow pigments present as to the decrease in size of the red crystals.

Mitchell (32) made a study of samples of tomato juice produced in 10 states as to color, solids, salt, and acid content. The best sample had a color rating of 6.47 and the poorest 11.94, with an average of 9.28. Gaylord and MacGillivray (14) discussed field and harvest factors affecting picking, but also indicated the color changes of a tomato as it ripens. Color improves very rapidly if the tomato is a cull because of poor color and very slowly if it is a U. S. No. 1. The colors at the time of change from a cull to a U. S. No. 2 and from a U. S. No. 2 to a U. S. No. 1 are similar to those previously mentioned. Another closely related piece of work (Gaylord and MacGillivray 15) concerns the use of different quality lights for color grading in connection with the federal standards. The quality of light on the grading table affected the accuracy of grading. A light from 5500 to 6500 degrees Kelvin seemed best.

Sparks (43) used Munsell discs to measure the color of Red McClure potatoes grown under different nutritional conditions. Ten circles were arranged so that they had different areas of 10 YR 8/6, and 2.5 R 4/10 discs. A uniform color was obtained by spinning these discs as well as the potato sample. If the author's mean color referred to in the tables is per cent of 2.5 R 4/10 disc, the extremes in color expressed in the tables represent hues of 8.6 R to 2.0 YR, but chroma varies only from 5.56 to 6.3.

In the development of canned food grades (P. M. A. grades

U. S. D. A.), color is an important consideration. In the first grades the desired color was frequently expressed in terms of areas of Munsell discs. Tomato juice grade, which was effective in 1938, indicated a color rating of 9.8 for color in grade-A juice, and similarly a color of 11.4 for grade-C juice (see Table I). The canned tomato grade which was effective in 1941 indicated the use of colors given in Maerz and Paul's Dictionary of Color (27). About 1940, the Federal Food and Drug Administration (50) published a minimum color for standard canned tomatoes under the McNary-Mapes Amendment to the Pure Food Law. This standard was expressed in terms of Munsell discs, and was a color rating of 14.6.

Worthy of consideration is research work dealing with different illuminants; relationship between Munsell, spectrophotometer, and tristimuli measurements; as well as the number of different colors. Specifications for standard illuminants have been established, and have been identified by letter of the alphabet (Nickerson 36, 37, 38). "Illuminate C" has a color temperature of 6300 to 7000 degrees K, and is similar to that used in tomato color determinations. With cotton grading, a higher color temperature, or about 7400 degrees K, is desirable. It has been suggested that this be called "Illuminate D". Sixty-eight foot candles of light are desirable for cotton grading.

Kelly, Gibson, and Nickerson (18) used four different illuminants, and obtained spectrophotometer data and tristimulus values for several Munsell discs. The work of Newhall, Nickerson and Judd (34) indicate that there is a slight inaccuracy in the expression of Munsell notations. Nickerson and Newhall (39) made a study of the preceptible differences in color. One chroma step has five perceptible increments; one hue step has two; and one value step has 50 perceptible increments. This study would indicate that there were 7½ million perceptible colors as compared with an estimate of 10 million made by Judd. This is a considerable increase from the estimate made by Borings in 1939, 300,000, and that made by Titchner in 1896, of 33,000.

Color Measurements by Other Procedures:—There is a group of papers dealing with the measurement of color in terms of some empirical scale without regard to color attributes. These may be arranged according to pigments extracted and the amount determined; general appearance; and other colorimetric methods.

McCollum (26) extracted lycopin for quantity determination. Smith and Smith (41), and Smith (42) extracted the carotinoid pigments of the tomato for a quantitative determination. Went, LeRoseu, and Zechmeister (48) determined both lycopin and carotin by a chromatographic method of analysis. Jocoby and Wakes (17) used the same method to determine the lycopin and carotene content of rose hips and other fruits. Neusbaum (33) extracted the pigment from paprika pepper and compared the extract with a set of standards made with Naphthal Yellow S4. Miller and Winston (30) measured the relative color of oranges by extracting the carotinoid pigments and considering them in relation to vitamin A content. Barnes (5) used a carotin content to indicate the color of carrots as affected by soil moisture and temperature.

Amerine and Winkler (2, 3) used a Vino colorimeter to measure the color of wines. Readings are given in terms of color intensity determined by matching the sample with standard colors on a chart. Carrasco (6) reported the use of a Lovibond tintometer to measure the color of canned and dried tomatoes. Concentration of tomato juice was found to cause impairment of the red color. Baier and Higby (4) developed rotating spheres to grade citrus for color. These spheres had varying areas painted with green or yellow lacquers. Their eight spheres gave them sufficient range in color for the fruit to be classified. Both fruit and spheres were rotated. Miller, Cochran, and Garrison (31) recorded the color of carrots by the use of government color charts. Fertilizer and soil reaction had little effect on color. Variety, soil type, and height of seed bed affected color to different degrees.

The following workers report studies where the unaided eye was used to record poor and good color, or color differences: Allen (1), Combs (7), Magness (28), and Dugger (10).

In any color study the data may be more accurately interpreted if the colors are expressed in terms of color attributes. Many of the research workers using spectrophotometers and colorimetric methods fail to express their color determinations in this manner. If this had been done, the evaluation of these methods would have been greatly facilitated. The physical method of color measurement has a distinct advantage from the standpoint of not being affected by quality of light or the color vision of the observer. Some of the data referred to indicate that this method is not as accurate in recording small differences in color as is the psychological method such as the Munsell system. There is need for further evidence on this point. Small changes in tomato pulp color caused by the addition of water were satisfactorily recorded by MacGillivray (22). Likewise, the Munsell data reported by MacGillivray (25) gave more consistent differences in color of good, medium, and poor pulp than did the spectrophotometer data on the same samples.

There have been several different colorimetric methods used to measure color which do not permit expression in color attributes. Where an extracted pigment is used for color measurement, there is always the possibility of other pigments or plant tissues affecting the appearance and color of the horticultural product. This was found to be true in the case of the tomato (24). In spite of these objections, there seems to be considerably more agricultural information obtained by this method than by the use of the spectrophotometer. The methods used are numerous and may vary greatly in accuracy. There is also difficulty comparing the data obtained by one method with an empirical scale with another method having a different scale.

Of all the methods used the Munsell procedure has probably been used most widely as well as producing the greatest contribution to our horticultural knowledge.

METHOD OF COLOR DETERMINATION

In all instances of research, the work was performed in areas and at times when tomatoes were received at canneries where they were graded according to these two terms. The inspectors were constantly supervised to insure uniformity of interpretation. Samples of minimum or borderline "well colored" and "fairly well colored" tomatoes were obtained from these inspectors. Since the tomatoes were to be pulped, it was possible to examine interior as well as exterior color of the fruit. These fruits were taken to some convenient location where a dark room was available so that the Munsell color equipment could be used. Individual tomatoes were ground coarsely in a food grinder, and were then passed through a fine piece of screen wire to remove seeds, core, and skin. With smaller fruited varieties, such as San Marzano, several fruits were used as one sample. Except in the above case, the sample from an inspector was made up of four to six individual fruits, whose color was determined individually to obtain the average color of the sample.

Color determinations were made in a dark room with artificial light of 6300 degrees Kelvin (daylight) and with the aid of an optical comparator. With such equipment it is possible to make an accurate match between the Munsell discs and the sample of tomato juice. The area of the discs used to match the color was recorded, and the color attributes were determined by means of tables given in a previous publication (22). A more complete description of the equipment and method is also found in the above publication.

A description of hue, value, and chroma has been given in the introduction to this article. In the actual color matching, the operator asked himself three questions when he compared the tomato sample with the rotating discs: (a) is the tomato redder or yellower than the discs (hue); (b) is the tomato lighter or darker than the discs (value); and (c) is the tomato brighter or duller than the discs (chroma)? In order to make the whirling discs redder, the area of the red disc (5R 2.6/13) is increased in comparison with the yellow red disc (2.5 YR 5/12). In order to make a color darker, the area of the following discs is increased 5R 2.6/13 and N 1/0. To make a color brighter, the area of the two chromatic discs is increased (5R 2.6/13 and 2.5 YR 5/12). With a little experience, the operator can make a color match in less time than he can pulp the tomatoes. It is not unusual to make 12 color determinations per hour.

In this paper, color has been expressed as color rating (Fig. 1) instead of the three color attributes of "hue", "value", and "chroma". There is no indication that "value" is essential in specifying tomato color. There is a similar case in hay where only hue needs to be specified. In all these determinations, both hue and chroma were calculated according to the tables in the publication previously referred to (22) and then color rating was determined by the formula given in the same publication. This formula is as follows:

(13-chroma of sample) + hue of sample = color rating. Small numbers indicate the best color and color rating may be as low as 5 or as high as 18 with the discs used in this study (Fig. 1).

Results and Discussion

There is ample evidence that tomato color is an important quality characteristic. In grades of the United States Department of Agriculture, Production and Marketing Administration, for processed foods, a relative value of 25 out of 100 points for canned tomatoes and tomato catsup is assigned. For tomato pulp, 50 points are similarly assigned to color. Table I gives the minimum color ratings assigned to the different grades for these products. In some of the earlier grades, minimum colors were expressed in terms of Munsell discs; these have been converted to color ratings. Thus, the minimum color rating for fancy (grade A) pulp is 9.8 while standard pulp (grade C) may be as poor as 11.4. Under the McNary-Mapes Amendment to the Pure Food Laws, authority was given for the establishment of minimum quality standards for canned foods. This standard established for canned tomatoes would indicate a color rating of about 14.5 or some lower than the P. M. A. standard grade for canned tomatoes, which has a color rating of 11.4. The ratings given in Table I are considerably poorer in color than those found in the succeeding tables for fresh tomatoes. This is primarily due to the change in color during processing, as was pointed out by MacGillivray (22, 23, 24) and Taxner (45).

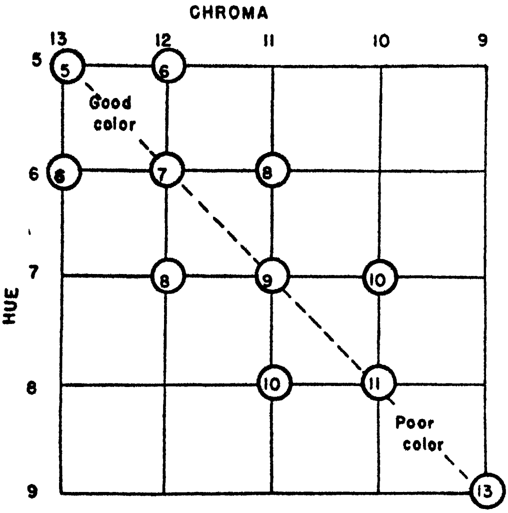

FIG. 1. Relation between color rating, hue, and chroma.

TABLE I—COLOR RATINGS OF FEDERAL CANNED FOOD GRADES FOR TOMATOES AND PRODUCTS

Type of Canned Food or Standard	Grade of Canned Food	Minimum Color Rating for Grade	Date Standard was Approved
Tomato pulp	A—Fancy C—Standard	9.8 12.7	Jan 1934
Tomato juice	A—Fancy C—Standard	9.8 11.4	Aug 1938
Catchup	A—Fancy C—Standard	9.8 11.4	Jan 1934
Canned tomatoes	A—Fancy C—Standard	9.8 11.4	Jan 1934
Pure Food Law: McNary-Mapes standard for canned tomatoes		14.5	

The data in Table II indicate the relative color interpretation of tomatoes in the Sacramento area in 1942 and in Sacramento and other areas of the state in 1943. The 1942 tomatoes in the Sacramento area were obtained primarily from inspectors in Woodland and Sacramento, with one sample from Stockton. The number of samples was fairly large, and the minimum well colored tomatoes had a color rating of 6.6 and the fairly well colored, 8.4. During this year, a committee of canners was selected to pick samples of tomatoes which would portray their interpretation of the terms "well colored" and "fairly well colored". These samples gave color ratings of 6.5 and 10.5. The "well colored" tomatoes checked closely with those selected by inspectors, but the "fairly well colored" were distinctly poorer in color. While no committee was appointed by the farmers, samples were obtained from five growers. Their selections of "well colored" was slightly poorer in color than either the inspector's or the canner's samples. As to "fairly well colored", the grower's samples checked closely with the inspector's, but showed a better color than those selected by the canner's committee.

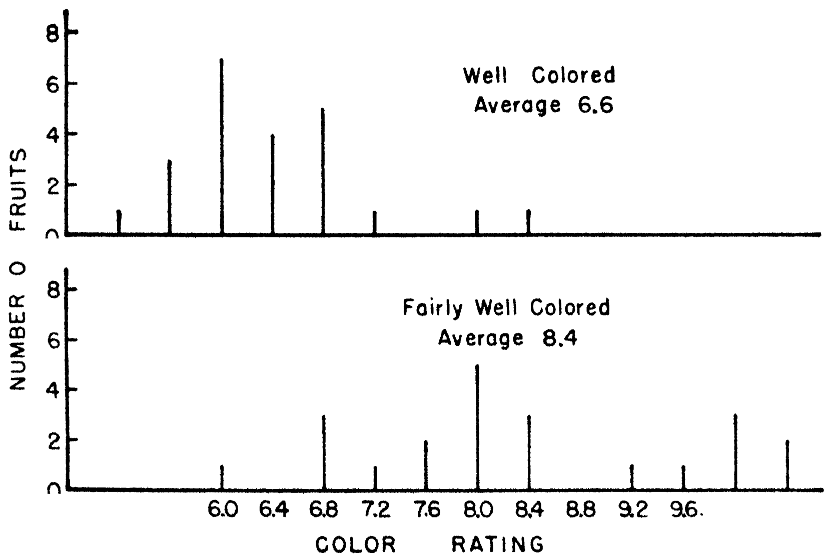

FIG. 2. Average color ratings of samples obtained from average individuals (usually six fruits per sample).

The data in Tables II and III are average color ratings. These data might be taken to indicate a very uniform interpretation of tomato color by the human eye, without objective measurements. Individual values in these averages show a predominant grouping in given areas of color rating but also many scattered values as shown in Fig. 2. Even with the most accurate judging of color there will be some range as to interpretation, but it is believed accuracy may be improved by objective color measurements. When the color of individual tomatoes is compared there is a wider range of color classification.

TABLE II—COLOR RATING OF TOMATOES SELECTED FOR MINIMUM WELL COLORED AND FAIRLY WELL COLORED*

Area	Person Selecting Samples	Color of Minimum Borderline Samples and Standard Samples			
		Well Colored		Fairly Well Colored	
		Number Fruits	Average Color Rating and Standard Error	Number Fruits	Average Color Rating and Standard Error
		1942			
Sacramento, Calif	State inspectors	131	6.6±.09	123	8.4±.15
	Canner's committee	15	6.5	15	10.5
	Five growers	28	7.1	33	8.5
		1943			
Woodland, Calif.. .	State inspectors	64	7.2±.09	64	8.5±.13
San Jose, Calif. . .	State inspectors	76	6.1±.08	76	8.2±.18
Stockton, Calif. ..	State inspectors	60	7.6±.11	60	9.2±.13
Los Angeles, Calif..	State inspectors	64	6.7±.07	64	9.0±.19
Burbank, Calif....	Federal inspectors	12	5.9	12	7.4
Grand average, state inspectors		392	6.8±.06	384	8.6±.08

*Similar studies were made in Indiana in 1931 and 1932. The 1932 results are similar to those obtained in California. The results obtained in 1931 were slightly poorer in color, and this seemed to be correlated with a season producing a smaller percentage of well colored tomatoes.

TABLE III—COLOR DETERMINATIONS MADE ON SAMPLES SELECTED BY SUPERVISING INSPECTORS

Date (1943)	No. Inspectors	Variety	Color Rating For Minimum Color For					
			Well Colored			Fairly Well Colored		
			No. Fruits	Color Rating Average	Frequency of Selection	No. Fruits	Color Rating Average	Frequency of Selection
Oct 22	6*	Pearson	7 to 9	7.1	4	26 to 29	9.8	4
Oct 29	16	Santa Clara	8 to 10	6.9	14	15 to 18	8.9	11
		Pearson	10 to 14	7.0	13	20 to 25	9.1	12
		San Marzano	11 to 17	6.6	12	25 to 29	9.4	11

*One person indicated range and so his results were excluded.

The work in 1943 consisted of obtaining similar data from inspectors in four areas of the State, namely Woodland, San Jose, Stockton, and Los Angeles. Each of these cities had an office for supervising inspectors, and the surrounding factories were furnished with inspectors from these offices. At Burbank, California, was a cannery which had purchased tomatoes for over 5 years on the basis of U. S. grades; therefore, a small sample was also obtained from the inspector of this cannery.

The data obtained from the four areas under State inspection gave minimum and maximum color ratings of 6.1 to 7.6 for "well-colored" tomatoes. The "fairly well colored" varied between 8.2 to 9.2. The data of the inspectors at San Jose averaged a better color for both minimum "well colored" and "fairly well colored", while those of the inspectors at Stockton were consistently poorest in color. If supervising inspectors had such comparisons available it would seem rea-

sonable to expect that within a week the inspectors could have their color checking within a difference of 0.5 step in color rating. The results obtained at Burbank indicated that redder and brighter tomatoes were selected for both "well colored" and "fairly well colored". Unfortunately, this sample, which was small, was from only one inspector.

In the fall of 1943, California was visited by one of the federal personnel who had previously visited eastern and midwestern canneries which purchased on the federal grade. It was possible, through the cooperation of state and federal supervising inspectors, to have two cuttings in October to select minimum "well colored" and "fairly well colored" tomatoes. These cuttings were held in Sacramento on October 22 and 29. Many tomato fruits were cut, and then arranged in order by placing the best fruit color first and the poorest color last. Fruits were numbered consecutively, beginning with "1" for the best color. Individuals then picked out the fruit or fruits which were borderline or the minimum for the two color classifications. These numbers were noted on a piece of paper, color determinations were made of the fruits, and the results were summarized. On October 22, six individuals selected fruits, of which seven to nine had an average color rating of 7.1. Similarly, the "fairly well colored" tomatoes had numbers from 26 to 29 and averaged 9.8. After this trial, another set of tomatoes was selected, and the group acted as a unit in selecting minimum colors for the two grades. Minimum "well colored" tomatoes had a color rating of 6.4; and minimum "fairly well colored" tomatoes of 10.1.

On October 29, the number of participants was increased to 16. and three varieties were considered separately. These results are given in Table III, and indicate that minimum "well colored" tomatoes varied from 6.6 to 7.0; and "fairly well colored", from 8.9 to 9.4.

As the result of these studies, it would seem desirable to select a range for interpretation of minimum "well colored" and "fairly well colored" tomatoes. Since a color difference of one-half step, or between 6.8 to 7.3, is the difference in color which is perceptible to the eye, there is some justification of selecting such a range. The range in color rating of 6.8 to 7.3 is suggested for minimum "well colored" tomatoes, and 8.8 to 9.3 for minimum "fairly well colored" tomatoes. Thus, the minimum difference between these two colors is 2, or four times the difference perceptible to the eye. In any color grading, uniformity of interpretation is probably more important than very high standards for the color.

Effect of Storage on Color Change

The magnitude of color change upon storage is of importance from two standpoints: (a) the rate of change should be known for our general knowledge; as well as (b) the effect of the storage period between inspection and canning on the color of the fruits. If the storage period is extensive, it may be disastrous because of mold and rot increase. Gaylord and MacGillivray (14) made a study of the average changes in color of tomatoes as they ripen. In the case of culls due

to poor color, the fruits improved rapidly in color, or there was a color rating change of 3.3 in 24 hours. As a U. S. No. 2, the change was less rapid, or 1.2 improvement in color rating, with U. S. No. 1's changing only 0.3 in color rating in 24 hours. These results would seem logical, as a partially ripe tomato improves in color rapidly, while a "well colored" fruit is subject to only a gradual color improvement.

The data obtained in California on this subject have been given in Table IV. Two varieties have been considered — San Marzano and Pearson. These results show some improvement of color with storage for 24 hours at 80 degrees F. Samples with poor original color gave

TABLE IV—EFFECT ON THE IMPROVEMENT IN COLOR OF WHOLE TOMATOES AFTER 24 HOURS' STORAGE AT 80 DEGREES F

Lot	Variety	Number Fruits	Color Rating Storage (Hours) 0	24	Change in Color
1	San Marzano	20	9.3	7.9	1 4
2	San Marzano	20	10.1	8.3	1 8
3	Pearson	15	9 5	8 7	0.8
4	Pearson	15	10.2	8.3	1 9
Six best colored fruits from lots 1 to 4		6	7.6	7.0	0 6
Six poorest colored fruits from lots 1 to 4		6	11.8	8.6	3 2

greater improvement of color upon storage. This same effect was further demonstrated when the color change was studied by averaging the results obtained with the six best colored tomatoes before and after storage. Likewise, results are given by using the six poorest colored tomatoes. These results were obtained by using whole tomatoes. Color was run immediately on half of the whole fruits, and was run on the others the next day. Preliminary results were obtained with quartered fruits, in which opposite quarters were used for immediate color determinations with each of the other two quarters stored. This method was not used because of possible changes caused by molds and rots.

COLOR DETERMINATIONS BY SEVERAL OBSERVERS

As indicated in the review of literature, the Munsell color method has been used fairly generally for several different problems. In this connection, it is of interest to know how closely determinations would correspond if made by different people on identical samples. The results found in Table V were made in the District of Columbia, Indiana, and New Jersey by four individuals working in separate laboratories. Unfortunately, the equipment used in all cases was not identical. In some laboratories substitute equipment was used for lighting and for the optical eyepiece. To obtain the samples for this study, 24 number 55 cans were filled from a 5-gallon can of pulp, then were exhausted, capped, and processed. This was repeated for three samples of pulp numbered 1, 2, and 3 in Table V. Two cans of each sample were submitted to each observer, and his color determinations were sent to the author. The data were sum-

TABLE V—COLOR RATING OF IDENTICAL SAMPLES OF TOMATO PULP (PUREE) DETERMINED BY FOUR DIFFERENT COOPERATORS IN FOUR DIFFERENT LABORATORIES

Color Analyzer	Color Rating of Pulp Samples		
	Sample 1	Sample 2	Sample 3
1	13.1	11.0	14.0
2	13.1	9.8	13.1
3	13.3	10.9	12.6
4	13.2	10.5	13.3
Average	13.2	10.5	13.3
Maximum difference from average	0.1	0.7	0.7

marized. The comparisons made upon sample 1 gave almost identical color for all four observers. The results for the other 2 samples of pulp varied more. A difference of 0.5 in color rating is about the magnitude of color difference which may be distinguished by the eye. In these terms, a difference of 0.7 in color rating would indicate a fair degree of accuracy between observers. Degree of accuracy could probably be improved through the use of identical equipment.

SUMMARY

Color determinations of tomatoes indicated a satisfactory interpretation of the color terms of United States Standards for Canning Tomatoes. There were isolated cases where the accuracy was undesirable, but it is thought that the objective color measurements would increase accuracy of grading. Such measurements would be helpful in using the same standards over a series of years.

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Comparative Yields of Seven Varieties of Pumpkins (Cucurbita Moschata) Adapted to the South[1]

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SINCE the introduction from Africa in 1932 (1) of a pumpkin known as "African Squash" and the discovery (1) that this pumpkin is highly resistant to the vine borer and the pickleworm, two varietal types have been selected from it. One, the Alagold, (Fig. 1) was developed by Isbell (2) and the other, the African Bell, by Cochran (unpublished). These two varieties are very similar in the deep orange color and high quality of the flesh, and in the tan color of the skin. However, they differ in size and shape (Fig. 1).

The original introduction is reported (2) to have shown much variability in shape and size of the fruits, the weight ranging from 2 to 20 pounds. Miller (3) crossed the "African Squash" with the Yellow Cushaw. This cross led to the development of the Longfellow pumpkin, which resembles the Yellow Cushaw in shape but is said to be superior to it in quality. This author considered that the "African Squash" was of the species *Cucurbita pepo*. Greenleaf (unpublished), using a three times selfed African Bell line investigated its crossability and taxonomic relationship with the Yellow Cushaw and the Tennessee Sweet Potato. Both crosses were readily obtained and the F_1 hybrids proved highly fertile as shown by pollen counts and seed set. This confirmed the previously expressed belief (1) that the "African Squash" belonged to the species *C. moschata*.

In this paper the writer compares the yields of seven varieties of the *Cucurbita moschata* group. These pumpkins, as a group, are relatively resistant to the vine borer and the pickleworm, and are, therefore, suitable for growing in the South during the summer.

The yield test was a randomized block with seven varieties, replicated four times. The soil was a Chesterfield sandy loam infested with nematodes. The seed was sown on May 24. Each plot consisted of two rows of seven two-plant hills each, spaced 6 by 6 feet. The four blocks lay side by side within one terrace, and the long dimension of the plots was up and down the hill. Each variety thus sampled the greater range in soil variability in this direction. The blocks were separated by three guard rows and one guard row surrounded the entire planting. The variety Kentucky Field was used for this purpose. All but two of the varieties tested are distinct in fruit shape and could be separated readily from one another at the time of harvest. The two varieties referred to are Kentucky Field and Large Cheese. They were obviously outcrossed and were segregating for color, shape, and size of fruits. Thus, they could only be separated by tracing the individual fruits to the parent hills. Much care was taken to assure a full stand. Correction for stand was made only when both plants of a hill were missing. There was only one such hill in a plot of African

[1]The writer acknowledges the counsel of Dr. T. A. Bancroft with the statistics and Dr. C. L. Isbell with the varieties.

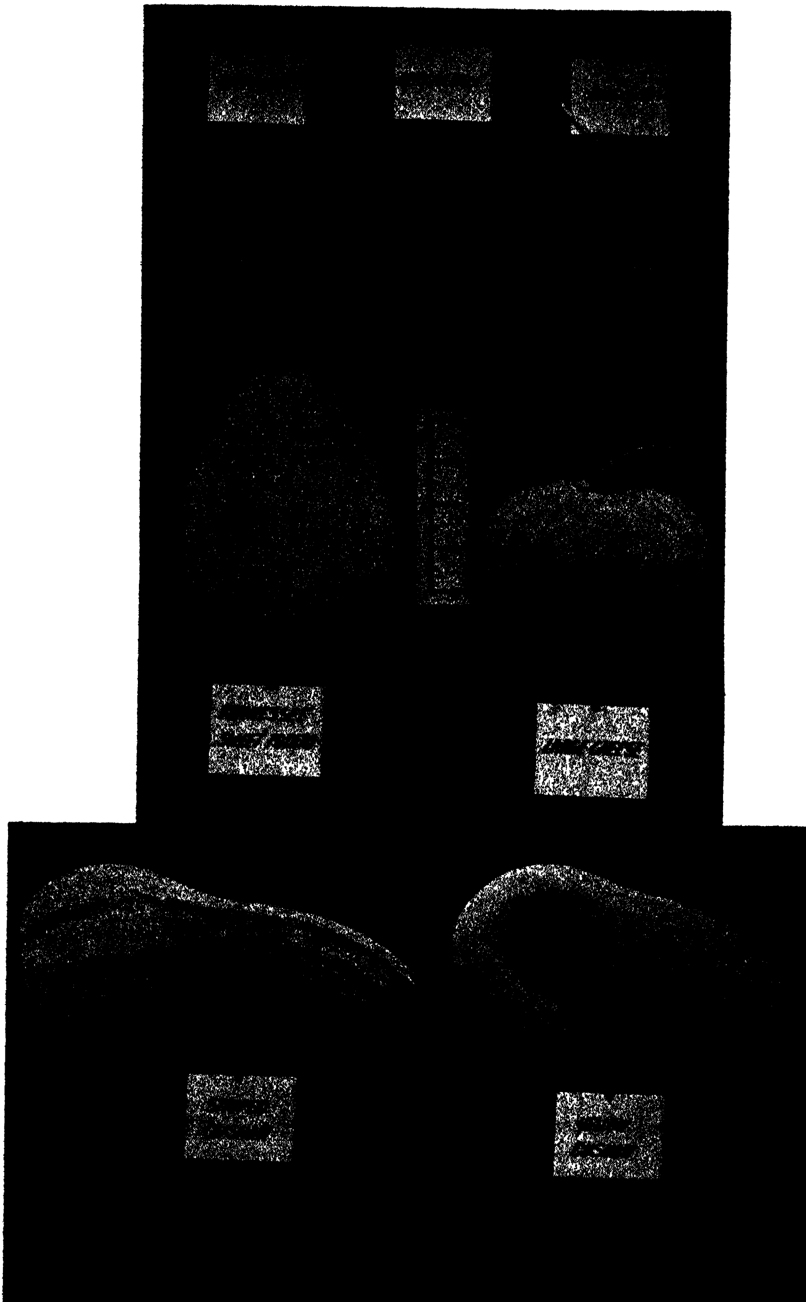

FIG. 1. The seven varieties of pumpkins of the Cucurbita moschata group that were included in the yield test.

Bell. The average yield of the remaining 55 hills was substituted for the missing hill before the data were analyzed. The varieties and the number of missing plants of each at the time when the plants were beginning to run were: African Bell 7, Alagold 3, Butternut 1, Tennessee Sweet Potato 2, Yellow Cushaw 2, Striped Cushaw 3, Large Cheese 1. The entire planting was dusted only once, on June 23, to control a heavy infestation of squash bugs and cucumber beetles. One thousand pounds of a 6–8–4 fertilizer per acre were applied in split applications of 500 pounds each; the first was applied in the row about 1 week prior to sowing and the second was applied around each plant just after they had started to produce runners.

Discussion of Results

The results of the yield test are given in Table I with a summary of the variance analysis. A comparison of the mean yields per plot shows that several of the varieties yielded more than others well be-

TABLE I—Yields, Number of Fruits and Fruit Weights of Seven Varieties of Pumpkins (Cucurbita Moschata)

Variety	Mean Plot Yield of Marketable Fruit* (Pounds)	Mean Number of Fruits Per Plot**	Mean Number of Fruits Per Vine	Mean Fruit Weight (Pounds)	Pounds Per Acre
Alagold	160.0	38.2	1.4	4.2	14,000
Large Cheese	299.5	30.0	1.1	10.0	26,200
Butternut	90.0	73.0	2.6	1.2	7,880
Yellow Cushaw	214.8	29.8	1.1	7.2	18,800
Striped Cushaw	256.5	22.8	0.8	11.3	22,440
African Bell (inbred)	150.4	51.5	1.8	2.9	13,160
Tennessee Sweet Potato	226.9	20.8	0.7	10.9	19,860

Summary of Variance Analysis

	Marketable Yield					Number of Marketable Fruits			
	Sum of Squares	D F	Mean Square	F		Sum of Squares	D F	Mean Square	F
Total	147,298.01	27	——	——	Total	9198.000	27	——	——
Blocks	3,115.2	3	1038.4	——	Blocks	145.142	3	48.4	——
Varieties	120,715.0375	6	20119.2	15.43**	Varieties	8278.000	6	1379.7	32.10**
Error	23,467.8	18	1303.8	——	Error	774.858	18	43.047666	——

*The least significant difference between plot means for P 19:1 = 53.6 pounds.
for P 99:1 = 73.5 pounds.
**F .05 = 2.66; F .01 = 4.01
The least significant difference for P 19:1 = 9.7 fruits
for P 99:1 = 13.4 fruits
The coefficient of variability for yield was 18.1, and for fruit number 17.3.

yond the .01 level of probability. In considering the absolute magnitude of the yields, it must be remembered that these pumpkins were sown about 1 month too late for maximum yields, and also that the two late varieties African Bell and Alagold probably suffered proportionately more from the early onset of extremely high temperatures and of fungus diseases (powdery mildew and anthracnose) than did the more rapidly maturing varieties. For season, the seven varieties were classified as follows: earliest — Butternut, Striped Cushaw; medium

early — Tennessee Sweet Potato, Large Cheese, Kentucky Field; medium late — Yellow Cushaw; late — Alagold, African Bell. It was noted during the early growth period that the vigor of the inbred African Bell was considerably less than that shown by the Alagold vines. It might, therefore, have been expected that the yield of the former would be less, but, as can be seen in Table I, the mean plot yield difference of 9.6 pounds was not significant. This confirms the findings of other workers (4, 5, 6, 7) of the relatively slight effect of inbreeding on the yield in cucurbits. The African Bell, however, produced a significantly higher number of fruits per plot. This result points to the possibility of developing new varieties with superior yields by crossing certain large fruited, high-yielding types that bear relatively few fruits with others that bear a significantly higher number of fruits. One such cross, Tennessee Sweet Potato x African Bell (inbred), appears promising in several respects. It is very productive, and has better shape, color and quality of flesh than the larger fruited parent. This cross also is entirely free from cracking during wet weather, a serious defect of the Tennessee Sweet Potato. That there is a great amount of variation between varieties in the amount of spoilage in the field can be seen from the percentage of defective fruits given in Table II. This is, in part, probably due to the greater susceptibility

TABLE II—Losses of Pumpkins Through Spoilage in the Field

Variety	Number Split Fruits	Number Spoiling	Number Rotten	Per Cent Defective Fruits
Alagold	0	2	1	1.9 (3/156)*
African Bell inbred	0	4	0	1.9 (4/210)
Large Cheese	0	5	5	7.7 (10/130)
Butternut	4	16	3	7.3 (23/315)
Tennessee Sweet Potato	20	2	16	31.4 (38/121)
Yellow Cushaw	0	17	4	15.0 (21/140)
Striped Cushaw	10	8	19	28.9 (37/128)

*Ratio of defective to total number of fruits in the sample.

to pickleworm injury of some of the varieties, notably Butternut. With the two hard-shelled varieties, Tennessee Sweet Potato and Striped Cushaw, however, an important cause that opens the way to rot-causing fungi is the splitting of the nearly full grown fruits during wet weather. It is noteworthy that the two "African Squash" derivatives showed only 2 per cent of spoiled fruits.

With the exception of two reports, one by Isbell (2), and the other by Ritchie (1), the literature contains no yield data on *Cucurbita moschata* type pumpkins. The former stated that his best plot of Alagold yielded at the rate of 8 to 10 tons per acre, and the latter reported a 9.5 ton per acre yield of "African Squash" on the basis of a ½-acre plot. Alagold yielded at the rate of 7 tons per acre as reported here. The yields of the other varieties ranged from 3.9 to 13 tons per acre for Butternut and Large Cheese, respectively. These yields, although low due to the late season, still compare favorably with those of other species of Cucurbita. Haber (4) reported averages of 4.5 tons per acre for three open-pollinated commercial strains and 8 tons for six inbred selections of Table Queen *(C. pepo)*. Hutchins and Croston

(5) reported the yields of several varieties of Hubbard squashes and of certain F_1 hybrids in this group. These ranged from 3.5 tons to over 21 tons per acre. Yields of essentially the same magnitude can be obtained in the *moschata* group.

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The Effects of Bud Pollination on Fertility and F_1 Fruit Characters of Some Chinese Brassicas[1]

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Brassicas are the most polymorphous of our cultivated plants. The genus is characterized by aneuploid numbers of chromosomes (12), and by the great variation of morphological characters, especially the vegetative organs. Since the variability of these morphological characters results from the differences in the ability of species and varieties to intercross, further information on the modes of pollination of other taxonomic species seems to be necessary for the understanding of the problem.

There is evidence that both common cabbage, *Brassica oleracea;* Chinese cabbage, *B. pekinensis,* as well as other genetically elementary species are highly self-incompatible (3, 4, 10, 13, 14). The fertility in selfing is closely associated with both physiological conditions (9, 14), and cytogenetic constitutions (6, 7, 12, 13).

In common cabbage, radish and Petsai, bud pollination or premature pollination has been used to increase the fertility in selfing, especially in those varieties which are highly self-incompatible (4, 5, 8). The ability of intercrossing of many Chinese brassicas was studied by Chen (1), Tai *et al* (16), and Sun (15), but few of these writers used bud pollination to increase the self-fertility of these species.

It is the purpose of the present paper to discuss the use of bud pollination to increase the fertility and compare the F_1 silique characters resulting from different methods of pollination.

Procedure

Three varieties representing two different species, *Brassica Chinensis* (x = 10), and *B. juncea* (x = 18), were used in this experiment:

Wu Ta Tsai (*B. Chinensis var. rosularis* Tsen et Lee),
Kao Yu Tsai (*B. juncea var. gracilis* Tsen et Lee),
Chi Kuan Tsai (*B. juncea var. celerifolia* Tsen et Lee).

Both ordinary selfing and bud pollination were done by enclosing the whole inflorescences. Paper bags 14 cm wide and 20 cm long, were used to cover the inflorescences before the opening of the flowers. If there were open flowers on the base of the inflorescence, they were removed in order to avoid any possible transfer of foreign pollen. The apical portions of the inflorescences were cut off in order to stop the elongation of the central axis. As a result, only about 10 flower buds of the middle portion of each inflorescence were enclosed. Five plants were used for each kind of pollination experiment. Two inflorescences of each plant were selected, one for ordinary selfing, one for bud pollination.

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[1]This experiment was done while the writer was with the Department of Horticulture, National Central University, Chungking (now Nanking), during the years 1944 and 1945.

The writer wishes to express his thanks to Dr. R. L. Carolus and Dr. E. H. Lucas for their criticism and assistance with the manuscript.

Bud pollination was carried out 4 days after bagging. The flowers from which mature pollen had been used were removed. The buds used usually would reach their normal opening time 2 days later. After the completion of this process, the whole inflorescence was enclosed again. In both ordinary selfing and bud pollination, the paper bags were removed after the fruits began to develop, about 1 week after pollination. Bud pollination, as described above, therefore, was also a selfing procedure. It differed from ordinary selfing in so far as mature pollen from mature flowers was applied to the stigmas of immature flowers (buds).

RESULTS

COMPARISON OF FRUIT SETTING FROM BUD POLLINATION AND ORDINARY SELFING

Wu Ta Tsai, *Brassica Chinensis var. rosularis*, an excellent variety of Chinese cabbage,[2] was found to be self-incompatible. The percentage of self-fertility can be increased by bud pollination. As indicated in Table I, the percentage of ordinary selfing is 15.9, and that of bud pollination is 74.3.

The self-fertility of the two varieties of mustard, *var. gracilis,* and *var. celerofolia,* cannot be greatly increased by bud pollination. Whether ordinary selfing or bud pollination is used, the fertility usually ranges from 80 to 90 per cent. There is no statistical difference between the results of ordinary selfing and bud pollination. These varieties usually are self-compatible.

TABLE I—PERCENTAGES OF FRUIT SETTING AFTER BUD POLLINATION AND ORDINARY SELFING IN SOME CHINESE BRASSICAS

Varieties	Method of Pollination	No. Flowers Pollinated	No. Siliques Set	Per Cent Siliques Set
Brassica Chinensis var. *rosularis*	O.S.*	88	14	15.9
	B.P.	35	26	74.3
Brassica juncea var. *gracilis*	O.S.	51	46	88.2
	B P.	33	27	81 8
Brassica juncea var. *celerifolia*	O.S.	46	38	82.6
	B.P.	36	30	83.3

*O.S. = ordinary selfing; B.P. = bud pollination.

F_1 FRUIT CHARACTERS RESULTED FROM DIFFERENT MODES OF POLLINATION

Chinese Cabbage (Brassica Chinensis L.):—The variety used here is Wu Ta Tsai, *var. rosularis.* From the data in Table II, it is evident that there are great differences in the number of seeds per fruit resulted from various modes of pollination. Obviously, the fruits resulting from ordinary selfing contain less seeds per fruit (3.6 ± .72), and

[2]The common name "Chinese cabbage" is used here to indicate both *Brassica Chinensis* and *B. pekinensis*. However, some authors, such as L. H. Bailey, regarded *B. pekinensis* as Chinese cabbage or Petsai, and *B. Chinensis* as Pakchoi.

with greater variability (c.v. = 19.88). Those from bud pollination produced 13.6 ± .34 seeds per fruit, and those from natural pollination 19.0 ± .37 seeds. Hence, bud pollination increased the numbers of seeds per fruit, but did not equal natural pollination.

So far as the length of the fruits is concerned, the difference between those from natural pollination and bud pollination is not significant. However, the difference between those from ordinary selfing and those from bud pollination or natural pollination is statistically significant. Bud pollination increased the length of the fruits, and the length of the fruit stalks and beaks.

Mustards (Brassica juncea Coss.):—Two varieties of mustards, var. gracilis, and var. celerifolia, were examined. The number of seeds per fruit was greater in those from natural pollination (19.9 ± .35). Those obtained from ordinary selfing produced 17.6 ± 1.28, and those from bud pollination 16.8 ± .61. No significant difference in seeds per fruit was found between those ordinary selfing, and those from either bud pollination or natural pollination. Fruits which resulted from bud pollination contained less seeds per fruit than those from natural pollination as well as ordinary selfing.

Fruits produced by natural pollination were somewhat longer than those produced by bud pollination. However, in this instance, only small differences were observed between the three kinds of pollination so far as fertility and fruit characters were concerned. Bud pollination cannot be used as a method to increase the number of seeds per fruit or the length of the fruits.

The variability of the length of fruits and the number of seeds per fruit vary greatly owing to different methods of pollination. With both Chinese cabbage and mustard, the variability was found to be greater in ordinary selfing, and smaller in natural pollination. Chinese cabbage (x = 10) has a greater coefficient of variability than mustard (x = 18). Obviously, this is due to the fact that the former is self-incompatible.

TABLE II—DIFFERENCES BETWEEN F_1 FRUIT CHARACTERS OF SOME BRASSICAS WITH RESPECT TO THE METHODS OF POLLINATION

Variety	Method of Pollination*	No. Fruits Measured	No. Seeds Per Fruit	C.V.	Length of Fruits† (Cm)	C.V.
Brassica Chinensis var. *rosularis*	N.P.	50	19.0±0.37	1.94	3.87±0.098	2.53
	B.P.	20	13.6±0.34	2.50	3.84±0.066	1.72
	O.S.	13	3.6±0.72	19.88	1.74±0.093	5.34
Brassica juncea var. *gracilis*	N.P.	50	19.9±0.35	1.75	3.72±0.034	0.91
	B.P.	20	16.8±0.61	3.63	3.38±0.068	2.01
	O.S.	20	17.6±1.28	7.27	3.51±0.163	4.64
Brassica juncea var. *celerifolia*	N.P.	50	10.9±0.29	2.65	1.91±0.023	1.20
	B.P.	24	10.7±0.39	3.64	1.95±0.033	1.69
	O.S.	24	9.4±0.44	4.67	1.94±0.045	2.31

*N.P. = natural pollination; B.P. = bud pollination; and O.S. = ordinary selfing.

C.V. (coefficient of variability) = $\frac{\text{S.D.}}{\text{Mean}} \times 100$

†The length of fruits here measured is the length of the fruit bodies (actually the carpels). It excludes the apical beaks which usually contain no seeds.

Discussion

It has been known that bud pollination or pseudo-fertility can be used to increase the fertility of many self-incompatible species of Brassica. However, the extent of increase varies greatly from species to species.

It was suggested by Kakizaki (4) that the increase in fertility by bud pollination is caused by the slow rate of growth of the pollen tube, this being possibly due to the presence of a substance which inhibits its growth in the stylar tissue. According to Kakizaki (4), the fertilization caused by bud pollination of incompatible species, such as common cabbage and Chinese cabbage, is due mainly to the lack of inhibiting action in the immature style, and also to the longer time available for the growth of the pollen tube. This inhibiting substance is thought to be hormonal in nature. However, no chemical evidence has been found.

Because of the great differences among various species, the genetic constitutions should be considered. According to the work done by Morinaga (7), the cultivated species of Brassica may be classified into two groups based on the cytogenetic characters: (a) elementary species which include *Brassica Chinensis*, *B. pekinensis* (x = 10), *B. nigra* (x = 8), and *B. oleracea* (x = 9); and (b) amphidiploid species which include *B. juncea* (x = 18), *B. napus* (x = 19), and *B. carinata* (x = 17). The amphidiploid species were found by Sikka (12), and Morinaga (7) to be originated from the chromosome doubling of the hybrids of the elementary species. It was considered that the elementary species were self-incompatible, while the amphidiploid species were self-compatible. The results of the present experiment prove that this explanation is suitable.

Wu Ta Tsai, a variety of Chinese cabbage, with 10 pairs of chromosome, is self-incompatible. The fertility of it, therefore, can be increased by bud pollination. On the other hand, both Kao Yu Tsai (Chinese means tall oil-yielding mustard) and Chi Kuan Tsai (means cockcomb mustard), which belong to the species *Brassica juncea*, with 18 pairs of chromosomes, are self-compatible. The fertility of them, therefore, cannot be increased by bud pollination.

So far as the number of seeds per fruit and the length of fruit are concerned, Sun (15) placed the brassicas into three groups — large, medium and small. But no definite relationship can be concluded from the genetic constitutions. In crosses of varieties of *Brassica juncea* with one another, Sinskaia (13) found the percentages of castrated flowers having set siliques to be of an average value of 91.3, while in crosses of *B. juncea* x *B. Chinensis* only 35.2 per cent of flowers produced siliques. A higher set of good seeds per fruit is usually produced from the cross of a high chromosome number female with a low number male than the reciprocal (2, 18). The division of groups suggested by Sun (15), therefore, seems to be unnecessary.

Summary

1. The purposes of the present experiment were to find out which species or varieties of some Chinese brassicas are self-compatible or

self-incompatible, and in which of them the fertility may be increased by bud pollination.

2. The varieties used in this experiment were Wu Ta Tsai, *Brassica Chinensis var. rosularis;* Kao Yu Tsai, *B. juncea var. gracilis;* and Chi Kuai Tsai, *B. juncea var. celerifolia.*

3. Of the varieties mentioned in this article, only *Brassica Chinensis var. rosularis* is self-incompatible. Fruit setting after ordinary selfing was 15.9 per cent, while bud pollination increased it to 74.3 per cent. The varieties belonging to *B. juncea* are self-compatible. Their percentages of fruit setting after ordinary selfing and bud pollination do not differ significantly.

4. The seeds per fruit of *Brassica Chinensis var. rosularis* obtained after natural, bud-, and ordinary self-pollination are 19.0 ± 37, 13.6 ± .34, and 3.6 ± .72 respectively. In comparison with ordinary selfing, bud pollination has greater influence on increasing the number of seeds per fruit as well as the length of the fruits. In *B. juncea,* there is no significant difference between the length of fruits resulting from the three different methods of pollination.

5. Coefficients of variability of the fruit characters, regardless of variety, are higher in ordinary selfing, lower in bud pollination and still lower in natural pollination. Among the three varieties here used, Wu Ta Tsai is the most variable one.

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Vernalization and Seed Stem Development in Lettuce

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Many reports have been published on the influence of vernalization in hastening maturity and seed production in crop plants, the cereal crops in particular. Three papers which present evidence to show that emergence of the lettuce seed stem from the head is hastened by vernalization, Gray (1), Simpson (2), and Warne (3) have come to the attention of the writers. Warne reports that vernalized lots of the variety Feltham King reached flowering stage 31 days ahead of untreated lots of the same variety. Simpson obtained a difference of 20 days in bolting and of 26 days in maturing seed between vernalized and untreated lots of the variety "Ideal", the vernalized lots being earlier. In Gray's experiment, vernalized plants produced seed stems 14 to 20 days ahead of untreated checks.

It occurred to the writers that some use might be made of vernalization of lettuce seed as an aid in producing seed of certain varieties. Some of the very slow bolting varieties, like Great Lakes, Cornell 456, and Slobolt, are difficult to handle in commercial seed production due to the slowness of the seed stem to emerge from the head or rosette. It was thought that by practicing vernalization the slow bolting varieties might be made to develop seed stems more rapidly, thereby increasing seed production.

To determine the influence of vernalization on bolting in some of our own lettuce strains, an experiment was started in the spring of 1948. The present paper presents some of the results of the tests made thus far.

Materials and Methods

Two strains of lettuce were selected for the work. Seed of the variety Slobolt was selected as one of the two to be tested, since it is one of the slowest to bolt of all of the varieties now commercially available. A fairly fast bolting strain, Cos 3288, was selected as the second variety.

A quantity of seed of each variety was placed in a small amount of water in a petri dish in the laboratory at 8:45 a m, January 28, 1948, and held until 1:00 p m, January 29, when a few of the seed showed radicles emerging through the seed coats. The petri dishes were then covered and placed in a cold chamber at 1 to 2 degrees C and held for 28 days, until 8:30 a m, February 26.

At 4:00 p m, February 24, a check lot of the original seed of each variety was placed in a small amount of water in a petri dish in the laboratory and held until 4:00 p m, February 25, when radicles first began to show. The check lots were then placed in a low temperature chamber to retard growth until February 26 when all lots were removed from the cold chamber and planted in soil in the greenhouse.

The plants were grown from planting to harvest in a steam-sterilized compost which had been permitted to lie piled long enough to elimi-

nate the bad effects that often arise from the use of freshly sterilized soil for plant growing.

When the seedlings were large enough (March 3) they were pricked-off to flats allowing a 2-inch spacing each way. Two weeks later (March 17) the plants were shifted from the flats to 4-inch clay pots. On April 20, 36 plants of each treatment (144 plants) were transplanted from the 4-inch to 10-inch clay pots. All four lots were placed on a centrally located bench in a greenhouse and permitted to remain undisturbed until all records were completed.

The methods used were believed to be comparable to those employed by Gray (1), Simpson (2), and Warne (3) and that comparable results could be expected.

All of the plants of a variety were permitted to grow and develop seed stems until the last plant of the variety had bolted and had a stem 8 to 10 inches or longer. The length of stem of each plant of the variety in both vernalized and untreated lots was measured from the soil level to its tip. The plants were destroyed soon after taking stem length records and no data was obtained of dates of first flower anthesis.

The data thus obtained were used to determine the influence of the vernalization treatment on seed stem development.

The faster bolting variety Cos 3288 was measured May 27 and the slow bolting Slobolt was measured June 23.

Results and Conclusions

Analysis of this data shows the mean length of stem of Cos 3288 when measured May 27 to be 28.33 ± 1.65 inches for the 36 vernalized plants and 24.3 ± 1.60 inches for the 36 check plants. This gave a difference in mean length of stem for Cos 3288 of 4 inches with a standard error of ±2.30. The mean length of stem in the 36 vernalized plants of Slobolt when measured June 23 was 28.75 ± .95 inches and for the check lot of Slobolt 25.7 ± 1.51 inches. The mean difference in stem length for Slobolt was 3.0 inches with a standard error of ±1.77.

Although there was a small difference in mean stem length in each variety in favor of the vernalized lot, the standard error of the mean difference in each variety indicates that the apparent difference in bolting rate was due to chance. At no time in the development of the seed stems was it possible to visually detect a definite difference in bolting between vernalized and check lots. Under the conditions of these experiments, vernalization does not offer any aid in hastening bolting in the two varieties of lettuce tested.

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Correlation of Soil Test Results with Celery Plant Growth[1]

By J. F. DAVIS and KIRK LAWTON, *Michigan State College, East Lansing, Mich.*

UNDER Michigan conditions plants for the early celery crop are grown in greenhouses. It is the purpose of this report to present the results obtained in a preliminary study of celery plant production.

Specific conductance has been used as a criterion for determining the range in soluble salt content that plants will grow satisfactorily (2, 3, 4).

A study of the relationship between celery plant growth and rate of fertilizer application was instituted and an attempt made to correlate the growth with specific conductance and other soil tests (nitrate, ammonium, phosphorus, and potash).

PROCEDURE

Celery seed (Summer Pascal) was planted in flats 4 square feet in area divided into 1-foot square sections. The flats were filled to a depth of 5 inches with muck that had never been previously fertilized. A commercially prepared 3–9–18 fertilizer was thoroughly mixed with the muck on February 16 at the following rates per acre, 0, 1, 2.5, 5, 8, 15 and 20 tons. The treatments were replicated four times with the exception of the 0 and 20 ton rates which were replicated twice.

Seed was planted on March 1 and the flats sampled March 22. Photographs were taken March 20 of the seedlings and of the transplants April 23 to show the differences in growth of plants of the various treatments.

After growth notations were taken on the original seedlings, the plants from unfertilized and 1- and 2½-ton-per-acre treated flats were transplanted back to all flats receiving the various fertilizer treatments. Observations were then made of the effect of fertilizer concentration on the development of transplants. Half of the flats receiving fertilizer were transplanted with seedlings taken from unfertilized flats, while in the other half, plants taken from either the 1- or 2½-tons-per-acre fertilizer rate were used. This procedure was used to determine the effect of initial fertilizer application on the subsequent growth after transplanting.

Soil samples for analyses were taken 3 weeks and 8 weeks after sowing the seed.

The soil samples were screened through a 2-mm screen and air dried. Conductivity measurements were made with a Model R D–15 Solu-Bridge instrument of 1 : 5 soil : water extracts by volume. The soil reaction was determined with a MacBeth glass electrode. "Available" nitrate, phosphorus, potassium, and ammonium were extracted from the organic soils using a 1 : 4 soil : (0.018N) acetic acid extract

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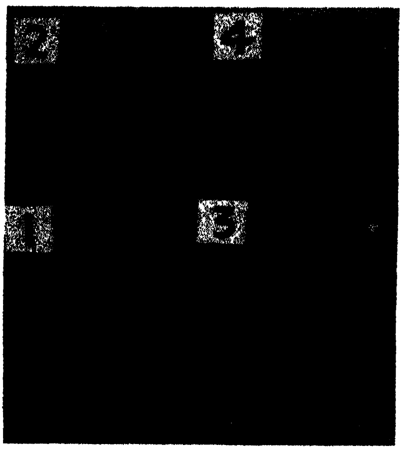
by volume and shaking for 1 minute. Nitrates were determined using brucine reagent; phosphorus using ammonium molybdate–HCl with 1-ammino–2-naphthol–4-sulfonic acid as the reducing agent; potassium using sodium cobaltinitrite; and ammonium using Nessler's reagent. All colorimetric comparisons for available nutrients except for ammonium were made with a photoelectric colorimeter. The samples were extracted with 1NKCl (1:4 by volume) for 1 minute and the ammonium content determined. The difference between the ammonium content in the two extracts was considered an estimate of the adsorbed ion.

Discussion of Results

The effect of rate of fertilizer application on the emergence and subsequent growth of the celery seedlings is indicated by Figs. 1 and



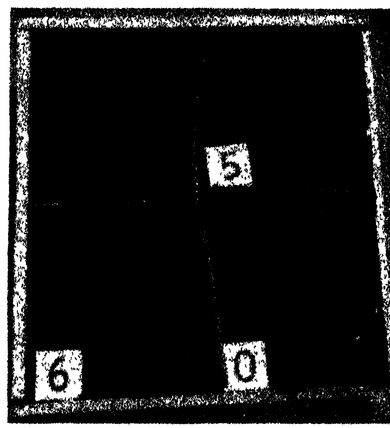
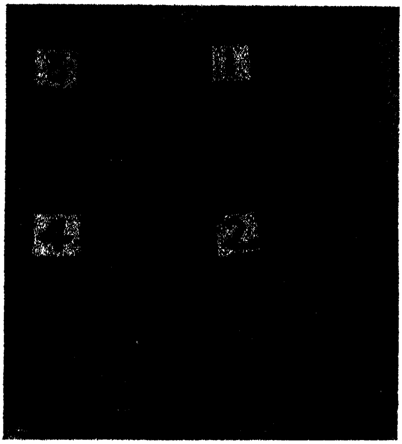


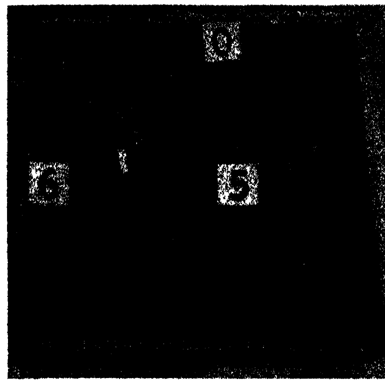
Fig. 1 and 2. The effect of fertilizer on growth of celery plants 3 weeks after sowing. 0–unfertilized; 1, 2, 3, 4, 5, 6–1, 2.5, 5, 8, 15 and 20 tons of 3–9–18 per acre.

2. Considerable delay in emergency and injury to stand occurred in the flats receiving 5 tons of 3–9–18 fertilizer per acre. As the rate of fertilizer increased beyond the 5-ton application the injury to stand increased and practically no plants survived with the 15- and the 20-ton treatments. With the 8-ton-per-acre application no plants suitable for transplanting were produced.

The effect of treatment on transplants is indicated in Figs. 3 and 4. The best plants were produced in the flats receiving either 1 or 2.5 tons of fertilizer per acre. As the fertilizer rate increased the plants became progressively smaller and at the 15- and 20-ton levels practically no plants survived. Transplants in the unfertilized flats grew very poorly. The relative size of the celery transplants, 3 weeks after transplanting in the 1-ton, 2.5-ton, 5-ton, and 8-ton treatments, is shown by Fig. 5.

An interesting observation on the experiment is demonstrated in





FIGS. 3 and 4. The effect of fertilizer on the growth of celery transplants 3 weeks after transplanting. 0–unfertilized; 1, 2, 3, 4, 5 and 6–1, 2.5, 5, 8, 15 and 20 tons of 3–9–18 per acre respectively. Seedlings transplanted in all the above treatments were taken from flats originally fertilized at rates of 1 or 2½ tons per acre.

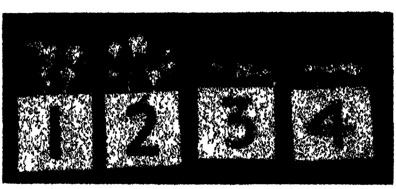


FIG. 5. Relative size of celery transplants grown in flats to which the following tons of 3–9–18 fertilizer were applied. 1–1 ton; 2–2.5 tons; 3–5 tons, 4–8 tons. Seedlings transplanted in all the above treatments were taken from flats originally fertilized at rates of 1 or 2½ tons per acre.

FIG. 6. Large plants — transplants taken from flat receiving 1 ton of 3–9–18 per acre. Small plants — transplants taken from unfertilized flat. Photograph taken 3 weeks after transplanting to a flat fertilized at the rate of 1 ton of 3–9–18 per acre.

Fig. 6. Seedlings from the unfertilized flats did not grow nearly as rapidly when transplanted into fertilized flats as did seedlings taken from flats fertilized with 1-ton of 3–9–18 per acre. This particular phase requires further investigation before any definite conclusions can be offered.

The data recorded in Table I indicates that the 3–9–18 fertilizer progressively decreased the pH of the muck by increasing the rate to 5-tons per acre. Further increases in rate of application increased the pH slightly.

TABLE I—THE EFFECT OF RATE OF FERTILIZER APPLICATION ON SOIL TESTS OF MUCK USED IN CELERY PLANT PRODUCTION, 3 WEEKS AFTER PLANTING

Tons 3-9-18 Per Acre	pH Range	Specific Conductance mhos $\times 10^{-5}$		Ppm in Soil Extract				
		After 3 Weeks	After 8 Weeks	NO_3	NH_4 (.018N)	NH_4* (ads.)	P	K†
1	5.75–6.10	61	43	27	2	8	4	63
2.5	5.60–5.70	106	83	42	5	6	9	151
5	5.55–5.65	165	175	71	21	4	25	304
8	5.75–5.85	226	255	46	35	25	40	595
15	5.80	313	345	39	75	75	106	1,070
20	5.75	402	340	45	100	125	139	1,500
No fertilizer	6.00–6.20	11	—	18	2	—	1	12
L.S.D......	(5 per cent level)	41.5	121	14.6	5.6	—	14.1	89

*These data represent the difference between ammonium obtained in the acetic acid extract from that in the K Cl extract.
†No formalydehyde was used to convert ammonia to hexamethylenetetramine.

In correlating specific conductance (1 : 5 soil : water) with growth a range between 61 and 106 mhos x 10^{-5} would appear favorable. Quite likely these limits could be further delineated by reducing the fertilizer increments in setting up treatment. Sweet and Peech (5) report a range of 75 to 175 for compost soil and 75 to 125 for field soils as optimum for tomato plant production under the conditions encountered in their work. Readings taken 5 weeks later show lower values for specific conductance and greater sample variation. The per cent error of the general mean as shown by the analyses of variance of the initial readings is approximately 10 per cent.

"Available" nitrate increased with an increase in rate of application up to the 5-ton amount and then decreased with each additional fertilizer increment. The "available" ammonium increased with each fertilizer increment and the adsorbed ammonium after the 8-ton rate was reached. It has been shown by investigators (1, 7, 8) that various forms of nitrogen are converted into ammonium so rapidly in soil so as to produce injury on cotton seedlings. According to Russell and Petherbridge (5) in a sand culture containing 16.7 per cent moisture 0.006 per cent (10 ppm) of nitrogen as free ammonia is injurious to germinating turnip seed and that 0.06 (100 ppm) per cent is fatal. Free ammonia has also been shown (6) to have an injurious effect on the growth of nitrate bacteria. These relationships and the above published reports suggest the need for determining the possible deleterious effect of ammonium on plant growth and nitrate forming organisms in celery plant production.

Phosphorus and potash contents increased as the rate of application increased. According to the data with the organic soil used in this work the start of poorer plant growth was associated with soil tests of 25 to 40 ppm of phosphorus and 300 to 600 ppm of potassium.

A few case histories are cited below in which an attempt was made to correlate the soil tests with actual growth conditions found in commercial greenhouses.

Case No. 1:—Excellent plants; pH 6.3, specific conductance 110 mhos x 10^{-5}.

Case No. 2:—Plants died; excess of chicken manure added; pH 6.8, specific conductance 155 mhos x 10^{-5}. In the same greenhouse where no application of chicken manure was made the pH was 6.5 and the specific conductance 72 mhos x 10^{-5}. Samples taken directly under a few plants in the area to which the chicken manure was added and where the plants were still growing vigorously the soil had a pH of 6.8 and a specific conductance of 63 mhos x 10^{-5}.

Case No. 3:—In one greenhouse the soil test showed a pH of 5.1 to 5.4 and specific conductance of 46–48 mhos x 10^{-5}. The plant roots were brown and plants lacked vigor. This trouble was diagnosed as Pythium root rot by Dr. Ray Nelson of the Plant Pathology Department of Michigan State College.

Case No. 4:—Plants not vigorous; pH 5.7–6.0 specific conductance 75–88 mhos x 10^{-5}; suspected gas injury from leaks in gas heater used for source of greenhouse heat.

Summary

Results of preliminary experiments in correlating celery plant growth with soil tests are presented. While it is realized that further work is required to arrive at more precise limits, the specific conductivity measurements provide an efficient aid in diagnosing troubles encountered in celery plant production.

According to these data the nitrate content cannot be correlated with rate of fertilizer application.

The importance and role of ammonium in soil diagnostic procedures requires further investigation.

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Effect of Hormone Sprays on Yield of Snap Beans[1]

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Several research workers have conducted experiments with various hormones in an effort to increase pod set of beans. The results of these experiments have varied depending probably on (a) the weather conditions prevailing during the experiment, (b) the kind of hormone and its concentration, (c) the form applied (dust, or spray), and (d) the variety used. Thus Allen and Fisher (1) reported 15 per cent increase in yield of wax beans by dusting them with App-L-Set and Parmone, commercial materials containing α–naphthaleneacetic acid. Application of these substances in the form of sprays did not show any beneficial effect. Moreover, Refugee beans did not respond to the application of these substances in either form. Hardenburg (3) did not obtain any increase in yield of pea beans by treating the seed with Rootone. There was a decrease in yield of various types of beans when dusted with Parmone containing 70 to 140 ppm of α–naphthaleneacetic acid, in spite of high temperature prevailing throughout the period of bloom. The toxic effect of the hormone was ascribed to its high concentration. Murneek *et al* (4) found that yield of snap beans may be increased or decreased by spraying them with 5 and 10 ppm of naphthalene acetamide or β–naphthoxyacetic acid, depending upon the temperature prevailing at the time of flowering. Fisher, Riker and Allen (2) working with canning snap beans tested a number of different hormones. They obtained a consistent increase in yield varying from 12 to 24 per cent by dusting twice with α–naphthaleneacetic acid (40 ppm). Spraying with the same hormone gave decrease in yield. They explained the detrimental effect of sprays on the basis of mechanical injury caused to blossoms as a result of high pressure. Less vigorous action of hormone in dust and longer contact was suggested as explanation for increased yield with dusts. However, no beneficial results were obtained by dusting or spraying Refugee beans. Wittwer and Murneek (6) concluded that an increase of 10 to 25 per cent in yield of snap beans was obtained under all conditions by spraying with p–chlorophenoxyacetic acid (2 ppm). They pointed out that under favorable growing conditions, increase in yield of snap beans was due to stimulated growth of ovarian tissue, whereas seed formation was depressed. A favorable response as regards yield was obtained by spraying Stringless Greenpod and Stringless Black Valentine; whereas Tendergreen and Tenderpod varieties did not respond to this treatment.

Wester and Marth (5) studied the effect of application of α–naphthaleneacetic acid to bush lima beans. They did not get any increase in yield when hormone was applied either as spray or as dust varying in concentration from 5 to 1000 ppm. The failure in response as indicated by yield was considered to be due to favorable prevailing temperature for pod set.

[1]Paper No. 306, Department of Vegetable Crops, Cornell University, Ithaca, N. Y.

The studies reported in this paper were undertaken to determine the effect of applications of four hormones on pod set of snap beans, under conditions prevailing at Ithaca, during portions of two growing seasons.

Materials and Methods

Two crops of Tendergreen variety of snap beans were grown; one during late summer and early fall of 1947 and the second during early summer of 1948. The hormone solutions were made by dissolving them in a small quantity of ethyl alcohol (10 c c) and later diluting with water to desired concentration. In 1947 a hand pump was used to spray the plants, while a 2-gallon knapsack sprayer was employed in the second year. Spraying was done at times of the day when it was comparatively calm. Seed was sown in rows 3 feet apart and lay-out of the experiments was so designed that alternate rows were guards to minimize the effect of drift. To facilitate presentation of results, the following abbreviations have been used.

BN β–naphthoxyacetic acid
ClPA p–chlorophenoxyacetic acid
ClPP α–o–chlorophenoxypropionic acid
2,4,5 T 2,4,5–trichlorophenoxyacetic acid

Experimental Results

The data obtained from two crops, one grown in 1947, the other in 1948, are presented below. As different treatments were given to two crops, the results are discussed separately.

The 1947 Experiment:—A late crop of beans was planted on July 16, 1947. This was in blossom on August 18th. Each plot consisted of a 12-foot row and each treatment was replicated three times. Every row was sprayed with 500 c c aqueous solution of hormone so as to have uniform distribution. Treatments given in Table I were started August 18. Mean maximum temperature for the period in which the bean plants were in bloom was 82.4 degrees F.

The pods were picked twice, on September 10 and September 26. There was no appreciable difference in yield as a result of different treatments for first picking (Table I). Average weight per pod was significantly increased by treatments involving the use of 2,4,5–trichlorophenoxyacetic acid. In the second picking it was seen that treatments with 2,4,5–trichlorophenoxyacetic acid depressed the yield, whereas a significant increase in yield was obtained in case of treatments Nos. 1 and 3. Total yield was significantly decreased by the application of 2,4,5–trichlorophenoxyacetic acid in concentrations used in this experiment. There seems a trend for increased yield in case of those treated with either p–chlorophenoxyacetic acid or α–o–chlorophenoxypropionic acid. However, statistically significant increase in yield was obtained only by application of p–chlorophenoxyacetic acid (2 ppm) twice a week. Factorial analysis revealed that out of the main effects, difference due to hormones was statistically significant, concentration just about approached signifi-

TABLE I—YIELD AND AVERAGE WEIGHT PER POD UNDER DIFFERENT TREATMENTS (MEAN YIELD PER 12 FOOT ROW)

Treatments	First Picking		Second Picking Yield (Lbs)	Total Yield (Lbs)
	Yield (bs)	Ave Weight Per Pod (Gms)		
1. ClPA: 2 ppm twice a week (5 sprays)	4.6	8.9	4.8	9.4
2. ClPA; 2 ppm once a week (3 sprays)	3.8	8.8	3.8	7.6
3. ClPA; 5 ppm twice a week (5 sprays)	3.1	9.2	4.7	7.8
4. ClPA; 5 ppm once a week (3 sprays)	3.4	9.0	4.3	7.7
5. ClPA; 2 ppm twice a week (5 sprays)	4.0	9.3	4.1	8.1
6. ClPP; 2 ppm once a week (3 sprays)	3.1	8.9	3.4	6.5
7. ClPP; 5 ppm twice a week (5 sprays)	3.8	9.1	3.8	7.6
8. ClPP; 5 ppm once a week (3 sprays)	3.5	9.1	4.0	7.5
9. 2,4,5-T; 10 ppm twice a week (5 sprays)	3.7	12.9	0.7	4.4
10. 2,4,5-T; 10 ppm once a week (3 sprays)	3.7	10.6	0.9	4.6
11. 2,4,5-T; 20 ppm twice a week (5 sprays)	2.0	11.4	0.5	2.5
12. 2,4,5-T; 20 ppm once a week (3 sprays)	2.5	11.0	0.5	3.0
13. Check (water) once a week (3 sprays)	3.6	8.5	2.8	6.4
Least significant difference (.05)	—	1.5	1.5	2.3
(.01)	—	2.0	2.1	3.1

cance and frequency of applications was not significant. None of the interactions, that is, hormone x concentration, hormone x frequency of applications, and concentration x frequency of application, was significant. As a result of this, frequency of application was left out of the experiment in 1948.

The pods obtained by p–chlorophenoxyacetic acid and α–o–chlorophenoxypropionic acid treatments were slender and longer than the check, while the ones treated with 2,4,5-trichlorophenoxyacetic acid were thicker, hollow and crooked. There was no difference in the seed development except in those treated with 2,4,5-trichlorophenoxyacetic acid which had fewer seeds.

The 1948 Experiment:—An early crop of beans was planted on May 28, 1948. Each experimental plot consisted of a 10-foot row, which was replicated eight times. The plants were in flower in the first week of July. They were sprayed thrice, at weekly intervals, beginning July 8. Eighty feet of row comprising a treatment was sprayed with 3 liters of hormone solution. Mean maximum temperature for the blooming period of this crop of beans was 83.4 degrees F.

Four pickings were made July 19, 26, August 2 and 13. Yield data from first picking were analyzed to get an idea of differences in early maturity by spraying with different hormones. Their effect on total yield was also studied by combining the yields from all pickings (Table II). All the comparisons are made with the check.

In general it may be said that hormone treatments increased early yields, although two of the eight increases are not significant. These treatments also tend to increase number of marketable pods at the first picking. In this case, however, none of the differences obtained by individual comparisons was statistically significant. Average weight per pod was markedly increased by certain treatments. In total yield there was significant decrease in case of treatments Nos. 1, 7 and 8 as compared with check. There was no significant increase in total yield from any treatment. However, treatment No. 4 just about ap-

TABLE II—EARLY AND TOTAL YIELD OF SNAP BEANS AS INFLUENCED BY DIFFERENT HORMONE TREATMENTS (MEAN YIELD PER 10 FOOT ROW)

Treatments	Early Yield			Total Yield		
	Weight of Pods (Lbs)	No. of Pods	Ave. Weight Per Pod (Gms)	Weight of Pods (Lbs)	No. of Pods	Ave Weight Per Pod (Gms)
1. BN (5 ppm)	1.6**	84	8.5**	6.7*	370*	8.2**
2. BN (10 ppm)	1.3*	86	7.1	7 3	431	7.6
3. ClPA (2 ppm)	1.4*	84	7.6	7.6	432	8.0*
4. ClPA (4 ppm)	1.3*	85	7 1	8 0	470	7.7
5. ClPP (2 ppm)	1.2	67	8.5**	7.2	409	8.0*
6. ClPP (4 ppm)	1.3*	75	7.8*	7 8	439	8.1*
7. 2,4,5-T (2 ppm)	1.2	70	8.1**	6.6*	370**	8.1*
8. 2,4,5-T (5 ppm)	1.4**	76	8.5**	6.2**	315**	8.9**
9. Check	1.0	66	7.0	7 4	438	7.6
Least significant difference (.05)	0.3	—	0.8	0.7	40	0.4
(.01)	0.4	—	1.0	1 0	—	0.6

proached the level of significance. There were fewer pods produced from plots treated with 2,4,5–trichlorophenoxyacetic acid and β–naphthoxyacetic acid (5 ppm) as compared to check. Increase in average weight per pod was maintained throughout by the same treatments.

It was observed that pods from the plants treated with β–naphthoxyacetic acid, p–chlorophenoxyacetic acid and α–o–chlorophenoxypropionic acid were slender and longer than the ones from check plots. However, those treated with 2,4,5–trichlorophenoxyacetic acid were again thick and curved. Pods from the treated plants were somewhat richer green in color than the check. There was no appreciable difference in the number of seeds per pod.

Ascorbic acid determinations were made of pods from plants treated with p–chlorophenoxyacetic acid (4 ppm), and α–o–chlorophenoxypropionic acid (4 ppm) and untreated ones. Results presented in Table III show that there were no statistically significant differences between these treatments.

TABLE III—EFFECT OF HORMONE SPRAYS ON ASCORBIC ACID CONTENT OF BEAN PODS

Treatment	Mgs of Ascorbic Acid Per 100 Gms of Pod (Fresh Weight)
1. ClPA (4 ppm)	24 9
2. ClPP (4 ppm)	22.6
3. Check	21.2

SUMMARY

Two crops of Tendergreen variety of snap beans were grown; one during late summer and early fall of 1947 and second during early summer of 1948.

β–naphthoxyacetic acid, p–chlorophenoxyacetic acid, α–o–chlorophenoxypropionic acid and 2,4,5–trichlorophenoxyacetic acid were applied in the form of sprays in various concentrations.

Early yield of beans was increased in most cases by hormone treat-

ments. Increase in total yield was obtained only by the application of p-chlorophenoxyacetic acid (2 ppm) applied twice a week to fall crop. Spraying the plants with 2,4,5-trichlorophenoxyacetic acid in concentrations varying from 2 to 20 ppm depressed the yield.

Pods from treated plots appeared to be of somewhat superior quality on account of dark green color, uniformity and greater length as compared to untreated.

No significant difference was found in ascorbic acid content of the pods from various treatments.

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Effect of DDT Insecticides on Plant Growth and Yield of Some Bush Lima Bean Varieties

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In breeding experiments on lima beans difficulty has been encountered from infestation by several kinds of pests that attack the crop. The more common of these pests are the Mexican bean beetle, *Epilachna varivestis* Muls., and leafhoppers, *Empoasca* spp. The plant bugs, *Lygus* spp., (1) have been associated with blossom drop. Besides affecting the crop yield, the feeding of these pests may mask the plant characters being studied. Therefore, the plant breeder needs an effective insecticidal mixture that will control the usual insect pests in order to obtain a true reading on the performance of the strains and varieties of beans with which he is working.

During the summer of 1947, at the Plant Industry Station at Beltsville, Maryland, 14 varieties of lima beans were being tested for varietal performance and processing quality. To protect these plants from insect attack and to determine the effect of DDT insecticides on the plants, one-half of each experimental plot of beans was treated with a DDT-rotenone spray, and the other half with a rotenone spray to serve as a check.

There is not much information available on the tolerance of lima beans to DDT when applied at concentrations used for field control. Dudley (2) and White (3) reported tests in which DDT insecticides were applied to lima beans without injury. The New Jersey Agricultural Experiment Station (4) reported the control of the potato leafhopper on snap beans and lima beans with DDT spray which caused a stunting of snap beans but no mention is made of injury to lima beans. Likewise, Michelbacher *et al* (1) reported the control of *Lygus* bugs on lima beans with DDT-sulfur dust, but they did not mention plant injury. Results by the University of Maryland (5) indicate that plants of Fordhook bush lima beans treated with a DDT spray produced heavier vines, more beans per vine, and larger beans than did the untreated plants.

Experiment I

In Experiment I the effect of a combined DDT-rotenone spray on the yield of the following 14 varieties of bush lima beans was studied:

1. Henderson
2. Clarks Bush
3. Peerless
4. U. S. 343
5. Maryland No. 5643
6. U. S. 245
7. Illinois 3d
8. Illinois 4f
9. Thorogreen
10. Early Thorogreen
11. U. S. 16–13B
12. U. S. 13–51
13. U. S. 345
14. Early Market

Three seeds were planted in hills spaced 1 foot apart in rows 3.25 feet apart. The variety rows or plots were 32 feet long and the varie-

ties were distributed at random in four replicated blocks. After the seedlings were up, each hill was thinned to one plant.

One half of each variety-plot was treated with a suspension spray containing 0.01 per cent of rotenone and 0.075 per cent of DDT. The remaining half of each plot was treated with a spray containing 0.01 per cent of rotenone without DDT. The source of DDT was a commercial wettable powder containing 25 per cent of DDT, whereas that of rotenone was cube root powder containing 5 per cent of rotenone. The rotenone was used in the entire experiment to control the Mexican bean beetle.

Applications were made with 3-gallon knapsack sprayers, a different sprayer being used for each insecticide in order to avoid contamination. The spray was applied thoroughly over the tops of the plants, and on each side of the row, and the quantity used for each application was recorded to the nearest pint.

A total of six applications were made, on the following dates: July 16, 20, 23, August 5, 13, 25. The first evidence of injury was observed early in August, at which time the plants had received three applications. In these first three spray applications, the four replicate plots that were treated with rotenone spray only had received a total of 14.25 gallons and those with the DDT-rotenone spray 14.6 gallons. Since the four plots of each treatment contained 2912 square feet or $^1/_{15}$ acre, technical DDT was applied at the rate of 1.36 pounds per acre. In the other three applications 16.4 gallons of rotenone spray alone and 16.1 gallons of the DDT-rotenone spray were applied. In all six applications a total of about 30.6 gallons of each spray mixture was applied, and plots sprayed with DDT plus rotenone received technical DDT at the rate of 2.8 pounds per acre.

In addition, a 330-foot row of U. S. 343, in another part of the field and not included in this test, was treated six times with a DDT-rotenone dust mixture. This dust mixture was prepared by diluting the 25 per cent wettable DDT powder and a cube root powder containing 5 per cent of rotenone with talc so that the finished dusts contained 3 per cent of DDT and 0.5 per cent of rotenone. This dust was applied at a total rate of 6.4 pounds of technical DDT per acre.

Effect on Plant Growth and Nature of Injury

Early in August, after the plants in Experiment I had received three applications, it was noted that the young leaves of U. S. 343 in the top of the DDT-sprayed plants were pale green or yellowish green in color as contrasted with the very dark green color of the lower leaves and of all the leaves of rotenone-sprayed plants. The internodes on DDT-sprayed plants did not elongate like normal plants, which gave this variety a dwarfed prostrated appearance. Many young leaves took on a mosaic-like appearance of white and light green areas and some of the leaves grew to maturity and then turned yellow and died. Some very young leaves were almost white and died later without maturing. The growing points of some plants turned brown and died. In a few cases, the complete plant eventually died. Experiment II confirmed observations of Experiment I.

The stunting effect of plant growth of U. S. 343, when the plants were 56 days old, is clearly shown in Figs. 1 to 3.

None of the other 13 varieties showed any injury or other effects resulting from the wettable DDT-rotenone spray.

Since so few insects were found on plots treated with DDT-rotenone and rotenone alone and adjacent areas, no conclusions are drawn as to effect of the treatment on insect control.

FIG. 1. U. S. 343 bush lima bean plants in the center damaged by DDT-rotenone spray while Peerless to the left and Maryland 5643 to the right were undamaged. U. S. 343 was the only variety out of 14 that showed any visible symptoms on the plants. Planted June 18; photographed August 13, 1947.

EFFECT ON POD YIELD

All of the pods from each variety were harvested and weighed on the date that the majority of the pods were "prime marketable". In most varieties this harvest included a small percentage of yellow and a higher percentage of flat or immature pods. These data are presented in Table I.

These data showed a significant difference in yield between some of the varieties and no significant difference in yield due to treatment for 13 varieties. In the remaining variety, U. S. 343 there was a significant difference in pod yield due to treatment. The plots sprayed with DDT plus rotenone showed a very significant decrease in yield for U. S. 343. The average yield for U. S. 343 from the rotenone-sprayed plants was 1844 grams, but only 385 grams from those sprayed with DDT plus rotenone. This amounted to a reduction in yield of 79 per cent.

FIG. 2. Two plants of U. S. 343 bush lima beans at right were injured by use of DDT-rotenone spray; while the two plants at left of the same variety but sprayed with rotenone only, showed no visible injury. Planted June 18, 1947, and photographed on August 13, 1947.

FIG. 3. Representative plants of U. S. 343 variety of bush lima beans 56 days old showing reduction in plant size caused by DDT-rotenone spray (left), compared with rotenone spray (right).

TABLE I—EFFECT OF SPRAYS CONTAINING DDT-ROTENONE AND ROTENONE ALONE ON TOTAL POD YIELD OF FOURTEEN VARIETIES OF BUSH LIMA BEANS, EXPERIMENT I (HARVESTED WHEN MAJORITY OF PODS OF EACH VARIETY WERE PRIME MARKETABLE)

Variety	Date Harvested (September, 1947)	Average Yield*	
		Rotenone (Gms)	Rotenone—DDT (Gms)
U. S. 343	8	1,844	385†
Henderson	2	2,853	2,787
Peerless	8	2,149	2,394
Clarks Bush	8	2,559	2,296
Maryland 5643	8	2,037	1,868
U. S. 245	2	2,823	2,642
Illinois 3d	4	2,293	2,164
Illinois 4f	4	2,564	2,544
Thorogreen	8	2,059	1,976
Early Thorogreen	4	2,549	2,343
U. S. 16-13B	2	2,615	2,354
U. S. 13-51	8	2,740	3,441
U. S. 345	4	1,733	2,050
Early Market	4	2,942	2,702

*Differences required for significance between means for varieties at 5 per cent point, 588 grams; at 1 per cent point, 786 grams.
†Significant decrease at odds of 99:1.

The plants in the 330-foot row of U. S. 343 in another part of the field that was not included in this test showed no apparent injury or reduction in yield following treatment with a dust mixture consisting of 3 per cent of DDT plus 0.5 per cent of rotenone at a total rate of 6.4 pounds of technical DDT per acre. The absence of injury from this treatment may possibly be due to the inferior sticking qualities of the dust as compared to the spray.

EXPERIMENT II

Since plant injury from DDT occurred on only variety U. S. 343 of the 14 varieties of bush lima beans involved in Experiment I, it was deemed desirable to obtain information on whether wettable DDT from various other commercial sources might cause the same type of injury to this particular variety. In Experiment II, therefore, the 25 per cent wettable DDT powder tested in Experiment I was compared in suspension sprays with four commercial wettable powders containing 50 per cent of DDT, and with a spray prepared in the laboratory from 10 per cent DDT dust plus sufficient wetting agent (decylbenzene sodium sulfonate) to provide 0.1 per cent in the finished spray. The check treatment consisted of a cube spray containing 0.01 per cent of rotenone. As in Experiment I the DDT-rotenone sprays contained 0.075 per cent of technical DDT and 0.01 per cent of rotenone.

These tests were made only on U. S. 343 and a sister line variety, Peerless. The planting was made on August 7 in sandy loam soil. The arrangement consisted of three blocks in which the seven treatments were randomized in each block. There was one row of U. S. 343 paired with a row of Peerless for each treatment in each block. Single rows spaced 3 feet apart consisted of 20 hills 1 foot apart. Three seeds were planted in each hill and after the seedlings appeared above ground they were thinned to one plant per hill.

Applications were made on August 26 and on September 3, 12, and 22. A separate 2½-gallon compressed-air sprayer was used for each insecticide to avoid contamination. On each date the sprays were applied at the approximate rate of 80 gallons per acre. This constituted a total dosage of approximately 2 pounds of technical DDT per acre.

Effect on Plant Growth and Nature of Injury

On September 3, one week after the first application, the same dwarfing effect and malformation of the plants of variety U. S. 343 was observed in all plots that were treated with the various DDT-rotenone sprays (Nos. 1 to 6), but there was none in the variety Peerless. No injury was observed, however, on these two varieties in the plots treated with rotenone spray only. By September 12 the injury was very pronounced, and this condition continued until October 1, when the plants were affected by a moderate frost. Fig. 4

Fig. 4. Top row shows how six different treatments of DDT in Experiment II dwarfed U. S. 343; treatment No. 7, consisting only of rotenone spray, did not affect plant development. Bottom row shows Peerless unaffected by any of the seven treatments.

illustrates the injured plants in the DDT-rotenone plots as compared with the uninjured plants of the rotenone plots. This photograph was taken on September 30, when the plants were 54 days old and 1 day before the plants were cut to obtain the fresh-plant weights.

Effect on Fresh-Plant Weight

The unexpected frost terminated the experiment when the plants were only 54 days old and prevented the plants from reaching their

maximum size and pod production. An effort was made, therefore, to on plant development by harvesting 15 plants from each plot and taking the fresh-plant weights thereof. This was done the morning of the frost and before the effects of the frost had interfered too much.

In taking these data the plants were cut at the ground line, tied in bundles and weighed. When harvesting was started at 8:30 a m, there was a small amount of dew on the plants and the sky was overcast. By 9:00 a m, however, the weather cleared and the plants appeared completely dry.

The average fresh weights of the plants so obtained were as follows:

	Peerless	*U. S. 343*
	Grams	Grams
Rotenone spray	1052	826
DDT-rotenone sprays	1123	601
Difference	71 ±94	225 ±35

The six DDT-rotenone treatments for each variety were averaged for this purpose as there was no difference in fresh weight of either variety due to source of DDT spray material. The analysis shows the following results:

1. There was no significant difference in fresh-plant weight between the Peerless plants that were treated with the DDT-rotenone sprays and those treated with spray containing rotenone alone.

2. The U. S. 343 plants treated with the DDT-rotenone sprays weighed significantly less than those treated with rotenone alone.

In the same planting one unreplicated row of each variety was treated with a dust mixture containing 3 per cent of DDT and 0.5 per cent of rotenone. The dusted plants were not visibly injured, and their fresh weights were about the same as those of plants treated with the spray containing rotenone alone.

The differences in U. S. 343 between the six DDT-rotenone treatments and the check treatment were very striking, as is shown in Fig. 4; whereas there were no visible differences between any treatments involving the Peerless variety.

It is of interest to mention at this point that Magruder and Wester (6) reported that Peerless (formerly U. S. 243) originated as the result of 10 generations of selection and inbreeding in the progeny of a cross between Fordhook bush lima and Sieva pole lima. U. S. 343 which has not been named or released by the United States Department of Agriculture is a sister line of Peerless bush lima bean.

U. S. 343 which has shown such dwarfing from wettable DDT sprays tested is also very susceptible to lima bean mosaic; whereas Peerless, which was not injured by the DDT spray, is resistant to mosaic, as has been reported by Pyror and Wester (7).

Incidentally, in a field experiment conducted by A. C. Foster and C. A. Weigel (unpublished data) during the season of 1947 no stunting effect was observed and no significant difference in yield was obtained from any of the DDT-dust treatments used on the Fordhook bush lima bean. However, treatments with 3- and 5-per cent

DDT-rotenone dust mixtures caused an increase in purplish-like russeted areas on prime marketable pods.

The injury to variety U. S. 343 bush lima bean may possibly have been due to the wetting agent in the wettable DDT spray powders used to make up these sprays. It is not known whether these chemicals were responsible for the injury, since no test was made with any wetting agent alone.

Summary

A wettable DDT spray containing 0.075 per cent of technical DDT or 0.625 pound per 100 gallons of water combined with rotenone applied at the total rate of 2.8 pounds of technical DDT per acre stunted the plants of U. S. 343 bush lima bean, and significantly reduced the yield of fresh marketable prime pods by 79 per cent in Experiment I. This was the only one out of 14 bush lima bean varieties that was injured and dwarfed.

A 3-per-cent DDT-0.5-per cent rotenone dust applied at the total rate of 6.4 pounds of technical DDT per acre had no apparent detrimental effect on plant development or yield of U. S. 343, which was grown in the same field but not included in the test of Experiments I and II. The absence of injury from the dust treatment may possibly be due to the inferior sticking qualities of the dust as compared with the spray.

In Experiment II wettable DDT sprays prepared with material from six different sources, and applied at the total rate of 2.0 pounds technical DDT per acre, and combined with rotenone caused a very significant reduction in fresh-plant weight of U. S. 343 bush lima bean variety, in comparison with rotenone alone as a check treatment; but, no significant difference in fresh-plant weight of Peerless was obtained from these treatments.

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Herbicides for Control of Weeds in Vegetable Seedbeds Also Control Root-Knot

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In the spring of 1947 root-knot evaluations were made on plants taken from a series of seedbeds which had previously been treated with chemical herbicides. Interest at the Vegetable Crops Laboratory up to this time had been directed toward a study of herbicidal materials which offered promise of weed control in vegetable seedbeds (1, 4). Two of the herbicides under consideration were known to have nematocidal properties. Chloropicrin (manufactured and sold as Larvacide) has been used for a long time in controlling parasitic fungi, nematodes, and weeds. Uramon has been shown to have nematocidal value by Tisdale (6), but a mixture of Uramon and Cyanamid has (2) a more beneficial effect on plant growth than Uramon alone. It has been suggested that a third material, 2,4–dichlorophenoxyacetic acid (2,4–D) may act as a stimulant to soil organisms (3), but no reports of its nematocidal properties has been found by the authors. Smith (5) reports a depressing effect on nitrification following soil applications of 2,4–D.

Procedure

Herbicides were applied in randomized blocks in each seedbed in such order that a single bed having all three could be planted at one time. Fertilizer was applied at the rate of 2000 pounds per acre 1 week prior to seeding. Two soils were used, a light sand (Leon), and a heavier soil (Manatee). Both had been under cultivation for many seasons and were known to be infested with nematodes. The plants used for root-knot evaluation when large enough for field setting, were dug from the center row of each herbicide treated plot. One group of five seedlings each was removed at intervals of 1½ feet, making nine groups of 45 plants, from each treatment. The harvested seedlings were rated: N (no root galls), M (0–5), H (more than 5). For the purpose of statistical analysis the M's were multiplied by two and the H's by five. Tomato and celery were the crops used in the experiment. The effect of herbicides on crops has already been reported elsewhere (1, 4).

Material and Methods

A 3:1 Uramon + Cyanamid mixture was used; 1.5 pounds per square yard on the heavy soil and 0.5 pounds per square yard on the light soil. Previous experimental work (1, 4) has shown that Uramon + Cyanamid applications must vary according to the type of soil upon which the seedbed is located. The material was broadcast uniformly over the soil surface and then mixed thoroughly to a depth of 4 inches. Intervals of 4 and 10 weeks were allowed to pass between treatment and planting.

Chloropicrin was applied at the rate of 2.5 cc per square foot as recommended by the manufacturer. Intervals of 2 and 8 weeks were allowed before sowing.

The ammonium salt of 2,4–dichlorophenoxyacetic acid was applied as a liquid application equivalent to 10 pounds per acre of free 2,4–D acid. Periods of 4 and 10 weeks intervened between seedings.

Discussion and Results

Chloropicrin, Uramon + Cyanamid, and 2,4–D plots (Table I) were all significantly better for the control of root-knot than the Check. None of the three herbicides was significantly better than any other as regards control.

TABLE I—Nematocidal Action of Herbicides as Affected by Time Interval*

Soil Treatment	Interval After Treatment†		Total Root-Knot
	4 Weeks	10 Weeks	
Check	121	462	583
Uramon + Cyanamid	156	4	160
2,4-D	214	26	240
Chlorpicrin	68	29	97
Significant difference odds 19:1	161		227

*For method of plant evaluation see text under procedure.
†2 and 8 weeks for chlorpicrin.

A consideration of time interval which elapsed between treatment and seeding shows (Table I) a significant increase in root-knot gall formation in the check plots for seedlings started in January over those started in December. All the herbicides give the reverse effect but this is significant only with 2,4–D.

Table II indicates that all the effect of nematode control is gained on the heavier type Manatee soil. However, Table III shows that on Leon soil both Uramon + Cyanamid and 2,4–D plots gave a significant reduction in the root-knot infestation on seedlings started in January when compared to those started in December.

The small numbers obtained from Chloropicrin plots regardless of time interval, Tables I and III, indicate that the action of this material is much faster than 2,4–D or Uramon + Cyanamid. The latter nematocides show (Tables I and III) very good control of nematodes on plants started in beds which had been subject to the action of the

TABLE II—Effect of Soil Treatment on Two Types of Soil for Nematode Control*

Soil Treatment	Soil	
	Leon	Manatee
Check	105	478
Uramon + Cyanamid	160	0
2,4-D	141	99
Chlorpicrin	66	31
Significant difference odds 19:1	161	

*For method of plant evaluation see text under procedure.

materials during a 10-weeks period. In the case of 2,4–D the method of application may have retarded its action. Applied to the soil surface, it was necessary for the material to be carried downward by subsequent watering. Further studies will be carried out to determine the best methods for applying 2,4–D as a nematocide.

TABLE III—The Effect of Herbicides (Nematocides) on Root-Knot Infestation on Two Types of Soil Over a Period of Time*

Interval Between Treatment and Seeding†	Check	Uramon + Cyanamid	2,4-D	Chlorpicrin
	Leon Soil			
4 weeks	55	156	129	58
10 weeks	50	4	12	8
	Manatee Soil			
4 weeks	66	0	85	10
10 weeks	412	0	14	21

Significant difference, odds 19.1 is 97.
*For method of evaluation see text under procedure.
†2 and 8 weeks for chlorpicrin.

Summary

The results of these tests indicate that Chloropicrin, Uramon + Cyanamid, and 2,4–D were effective in root-knot control. Chloropicrin had a more rapid action, but its cost and the difficulty encountered in handling would make the cheaper, slower acting materials more desirable if the results obtained in this test can be substantiated.

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Nutrient-Element Balance and Growth of Leaf Lettuce[1]

By R. A. Schroeder, *University of Missouri, Columbia, Mo.*

The growing of leaf lettuce in greenhouses as a winter crop is a common practice in Missouri. For the past several years growers have been complaining that their lettuce does not grow as rapidly as in the past. Particular reference is frequently made to the exceedingly poor growth during periods of cloudy weather. It is also commonly stated that nitrate of soda doesn't give its former "kick". Growers have attributed the retarded growth to a wide variety of causes such as, poor seed, running out of variety, disease, and improper fertilization.

The lettuce is grown upon what is commonly accepted as soils of very high fertility. The fertilizer practices have most commonly been that of heavy applications of manure and/or mushroom compost supplemented with top dressings of a nitrogen fertilizer which most frequently was nitrate of soda. Occasionally applications of a complete fertilizer or superphosphate alone were made.

A number of factors seemed to indicate that an improper balance of nutrient-elements might be a least one of the causes of the difficulty. An experiment, therefore, was conducted to determine if certain high fertility greenhouse soils might be supplying nutrients in an improper balance for the growth of lettuce.

Methods

Leaf Lettuce, Grand Rapids variety, was grown in the greenhouse during the winter of 1946–47. The plants were grown in 2-gallon glazed stone jars in a colloidal clay-vermiculite-nutrient substrate (1, 2). In the first experiment there were two levels of phosphorus addition 90 and 180 m e per jar, three nitrogen levels, 90, 180, and 270 m e, and three levels of calcium addition, 0, 90, and 180 m e. All combinations of the above made a total of 18 treatments. There were three replications of each treatment and three plants in each jar. Individual plants were harvested and weighed separately. Other nutrients added to the substrate in constant quantities were potassium (90 m e), magnesium (20 m e), and sulfur (20 m e). The colloidal clay carried and supplied minor elements in sufficient quantities so that there were no visual minor element deficiency symptoms.

In the second experiment there were three levels each of nitrogen and phosphorus at 90, 180 and 270 m e. Potassium additions were also varied at three levels 0, 90, and 180 m e. All possible combinations of the above made a total of 27 treatments. Differences in the osmotic pressure of the soil solution were minimized in all of the treatments of both the first and second experiments by holding the degree of saturation of the clay constant. This was accomplished by increasing or decreasing the quantity of clay as the cations added were increased or decreased.

[1]Missouri College of Agricultural Journal Series No. 1085.

RESULTS

The deleterious effect of additions of nitrogen can be easily seen from the data presented in Table I. The lowest yield of all treatments was in the highest (270 m e) addition of nitrogen group. All six treatments receiving 270 m e of nitrogen were within the nine treatments making the slowest and least growth. In only two cases out of a possible 18 did an addition of nitrogen result in even a slight increase in growth. Within the 90 m e nitrogen treatment differences in growth as great as 77 per cent resulted from the various combinations of phosphorus and calcium. The 180 m e nitrogen treatments had growth differences of as great as 90 per cent. The 270 m e nitrogen treatments gave yields varying by 772 per cent.

TABLE I—AVERAGED FRESH WEIGHT OF LETTUCE PLANTS (GRAMS) VARIABLE N, P, AND CA

Calcium* \ Nitrogen*	90		180		270	
Phosphorus*	90	180	90	180	90	180
180	159	158	71	121	34	63
90	126	181	91	74	44	96
0	102	152	123	135	11	73

*ME of nutrient added per jar.

In certain nutrient-element combinations, increments of calcium gave increases in yield. In some combinations the increments did not effect yield, while in others there was a decrease. With each calcium level the growth varied greatly depending upon the combination of other nutrients present. The effects resulting from calcium additions were of a much lower magnitude than those occasioned by nitrogen. Increasing the phosphorus from 90 to 180 m e resulted in increased growth in 16 out of 18 possible times. The greatest per cent increases were at the 270 m e of nitrogen levels.

In the second experiment with variable nitrogen, phosphorus, and potassium the increments of nitrogen in 16 out of 18 times gave reduced growth. Potassium increments in 17 out of 18 treatments produced greater growth. Increasing the phosphorus from 90 to 180 m e gave increased yields nine out of nine times. Raising the phosphorus from 180 to 270 m e, however, reduced growth in four out of nine cases. A number of examples of the importance of nutrient-element balance are to be seen in both Tables I and II. For example; in Table II, 90 m e of nitrogen furnished sufficient nitrogen to provide an

TABLE II—AVERAGED FRESH WEIGHT OF LETTUCE PLANTS (GRAMS) VARIABLE N, P, AND K

Potassium* \ Nitrogen*	90			180			270		
Phosphorus*	90	180	270	90	180	270	90	180	270
180	91	123	123	34	70	77	15	63	62
90	88	96	135	30	48	31	11	24	32
0	36	64	3	16	50	1	10	17	21

*ME of nutrient added per jar.

average plant of 135 grams when potassium was 90 m e and phosphorus 270 m e. With the same nitrogen and phosphorus levels but lowering the potassium to 0 m e addition the plants averaged 3 grams. Enough potassium was present, however, to result in plants averaging 64 grams when the phosphorus was lowered to 180 m e and the nitrogen held the constant at 90 m e. For another example; with potassium at 180 m e, nitrogen at 270 m e, and phosphorus at 90 m e, the growth was 15 grams. Increasing phosphorus to 180 m e resulted in plants of 63 grams. With phosphorus at 180 m e and nitrogen at 270 m e lowering the potassium from 180 m e to 90 m e lowered growth to 24 grams. The 90 m e of potassium was sufficient, however, to give plants of 135 grams when the nitrogen was 90 m e and the phosphorus 270 m e.

Summary and Conclusions

Leaf lettuce grown in the greenhouse during mid-winter shows marked response to nutrient-element balance. Additions of any of the following nutrient elements, nitrogen, phosphorus, potassium, or calcium, may result in either a decrease or increase in plant growth depending upon the quantity of other nutrients present. Nitrogen and potassium give evidence of growth responses of greater magnitude than calcium and phosphorus, but both calcium and phosphorus, under certain conditions, can markedly affect growth of leaf lettuce either detrimentally or beneficially. These data give credence to the thought that the practice of heavy manure and nitrate of soda applications without attention to other nutrient-elements, particularly phosphorus, can result in reduced growth of leaf lettuce.

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Nematode Control in Nutriculture

By WENDELL R. MULLISON, *Biochemical Research Laboratory, The Dow Chemical Company, Midland, Mich.*

WITHIN the past few years there has been an increasing interest in commercial applications of nutriculture. One new development has been the establishment by the United States Army of large outdoor installations in Ascension Island, British Guiana, Iwo Jima, Nanking, and Otsu and Chofu in Japan. The latter has 55 acres of bed surface and is reported to be the largest in the world. Sizeable installations have also been built on Curacao and Aruba, both in the Netherlands West Indies, and in an increasing number of places in Florida and California.

A problem which has arisen in certain of these installations is the severe infestation of the beds with the root-knot nematode *(Heterodera marioni)*. This condition has also occurred in such installations under glass. Therefore it was planned to determine the effectiveness of several soil fumigants as nematocides and to work out methods for their use in nutriculture.

EXPERIMENT I

Relative Effectiveness of Three Chemicals as Nematocides:— Ethylene dibromide, a dichloropropene-dichloropropane mixture,[1] and formaldehyde were the three chemicals which were tried. Water-dispersable concentrates of these three were first compounded, and from these the subsequent desired aqueous dilutions were later made. The concentrate of ethylene dibromide was made by compounding 50 per cent by volume (65 per cent by weight) of ethylene dibromide and 50 per cent by volume (35 per cent by weight) of Tween 80.[2] The latter was used as an emulsifying agent; other such agents could have been used as well. The dichloropropene-dichloropropane concentrate was made by compounding 50 per cent by volume (53.2 per cent by weight) of the original mixture and 50 per cent by volume (46.8 per cent by weight) of Tween 80. Commercial 40 per cent formalin was used as the concentrate for the formaldehyde. The various dilutions of these three concentrates which were used are given in Table I.

Six-inch clay pots were filled with a mixture of washed quartz sand together with sand in which tomatoes afflicted with root-knot nematodes had been growing. In addition, each pot had infested tomato roots incorporated into the sand. These included intact roots as well as some which had been put through a Waring blendor. A unit of six such pots was used for each one of the concentrations. As controls, six pots were filled only with washed quartz sand which had not been in contact with nematodes, and six additional pots were filled with contaminated sand; neither set of controls was chemically treated. The general method for each treatment consisted in submerging each unit for 24 hours in a particular concentration. The chemical was

[1]Dowfume N — A technical mixture of dichloropropenes and dichloropropanes.
[2]Manufactured by Atlas Powder Co., Wilmington, Del.

then removed from the pots by flushing thoroughly four times with water, which included one period of standing over-night between rinses. The pots were then planted with Globe tomato plants about 3 inches high. They were watered with a standard nutrient solution three times weekly, the intervening waterings being with tap water. The plants were grown for 6 weeks, then harvested and examined for nematode root-knots. Data are given in Table I.

TABLE I—RELATIVE EFFICACY OF THREE NEMATOCIDES AS SHOWN BY DEGREE OF PLANT INFESTATION

Concentration (Ppm)*	Ethylene Dibromide	Dichloropropene-Dichloropropane Mixture	Formaldehyde
1250	None	None	—
1500	—	—	Severe
2500	None	None	—
3000	—	—	Severe
5000	None	None	—
6000	—	—	Severe

*Ppm = parts per million by weight.

All controls grown in uncontaminated sand remained uninfected to the end; all of the checks grown in contaminated sand and left untreated were badly infested at the conclusion of the experiment.

EXPERIMENT II

Effective Concentrations of Ethylene Dibromide and the Dichloropropene-Dichloropropane Mixture as Nematocides:—It was thought desirable to determine if ethylene dibromide and the dicholorpropene-dichloropropane mixture could be used at lower concentrations and still be effective as nematocides. Inasmuch as formaldehyde gave no control at the above concentrations its use was discontinued. The same methods were used as in Experiment I. Data are given in Table II.

TABLE II—EFFICACY OF SEVERAL CONCENTRATIONS OF TWO NEMATOCIDES AS DETERMINED BY DEGREE OF PLANT INFESTATION

Concentration (PPm)*	Ethylene Dibromide	Dichloropropene—Dichloropropane Mixture
150	Slight	Slight
300	Slight	Slight
625	Very slight	None
1250	None	None

*Ppm = parts per million by weight.

Those controls grown in uncontaminated sand remained uninfected to the end, while those grown in the contaminated sand and left untreated developed severe cases of root-knot.

EXPERIMENT III

Effect of Increasing Length of Treatment on Required Concentrations of Two Nematocides:—A third experiment was run in order to determine whether the effective concentrations could be decreased by

increasing the length of treatment. The same methods and materials as before were used except that the amount of emulsifier was cut to 20 per cent by weight in the concentrates used before dilution. Data are given in Table III.

TABLE III—EFFECT OF INCREASING LENGTHS OF TREATMENT ON NEMATOCIDAL EFFECTIVENESS AS SHOWN BY DEGREE OF PLANT INFESTATION

Chemical and Concentrations (Ppm)*	Length of Treatment		
	24 Hours	48 Hours	72 Hours
Ethylene Dibromide 300	Moderate	Slight	Slight
Dichloropropene-Dichloropropane 300	Moderate	Very slight	None
Ethylene Dibromide 600	Moderate	Slight	Slight
Dichloropropene-Dichloropropane 600	None	None	None

*Ppm = parts per million by weight.

Those controls grown in uncontaminated sand remained uninfected to the end, while those grown in contaminated sand and remaining untreated were all severely infected. It should be further noted here that observations of plant growth during all these experiments showed no decrease owing to the treatments. The heights were taken at the conclusion of the experiments and no significant differences were found.

DISCUSSION

These experiments indicate that water dispersions of ethylene dibromide and the dichloropropene-dichloropropane mixture give promise of having utility for root-knot nematode control in nutriculture installations. It is interesting to note that both of these chemicals penetrated old tissue infested with root-knot nematodes sufficiently to give eradication. The evidence is such that trials by commercial operators might be warranted.

The following method is suggested:

1. Disperse dichloropropene-dichloropropane in water at a concentration of 600 parts per million by weight with the aid of an emulsifying agent. An equally effective procedure is to disperse ethylene dibromide in water at the concentration of 1250 parts per million by weight with the aid of an emulsifying agent. Ethylene dibromide is preferred because of ease in handling.
2. Cover the medium with either of the above solutions and allow to stand for 24 hours or longer. The storage tanks and the distributing system should also be treated.
3. Drain the solution containing the nematocide from the medium.
4. Wash and rinse the medium thoroughly three times with water.
5. Cover the medium with fresh water and allow to stand overnight.
6. Drain medium and rinse; the beds are now ready for planting.

It should be pointed out that the toxicity of the vapors of these chemicals is such as to make it possible to attain a hazardous concentration in the atmosphere. Therefore, in using these materials the operator should avoid breathing the vapors, particularly from the concentrates. If these chemicals are used in an enclosed area it should be well ventilated.

Summary

From these experiments it was evident that a water dispersion of a dichloropropene-dichloropropane mixture or ethylene dibromide gave complete control of the root-knot nematode (*Heterodera marioni*) in sand culture.

The dichloropropene-dichloropropane mixture was more effective at certain concentrations than ethylene dibromide. In a 24 hour treatment the former gave complete control at 600 ppm, whereas the latter gave complete control at 1250 ppm.

Formaldehyde at the concentrations used (1500, 3000, 6000 ppm) afforded no control of the root-knot nematode.

The application of a water dispersion of a nematocidal chemical holds promise as a convenient and practical solution to the problem of controlling the root-knot nematode in commercial nutriculture installations.

Observations on the Storage and Germination Characteristics of Angelica Seed

By CARL A. TAYLOR, *Salinas, Calif.*

ANGELICA ARCHANGELICA (officinalis) is widely used as a culinary herb in Europe and England, and to a lesser extent in the United States. The literature on the propagation of this species as well as general experience of its cultivators show considerable disagreement as to the keeping qualities of the seed.

Bailey (1) in 1892 stated that the seeds should be sown in September or March. However M. Grieve (2) states that the germinating capacity of the seeds deteriorates rapidly and they should be sown soon as ripe in August or September; also that propagation (by seeding) should not be attempted otherwise than by the sowing of ripe fresh seed. German (3) states "There is no doubt that Angelica seed loses viability in a very short time, perhaps a few weeks. I'm quite sure it's not a question of dormancy". However Rulofson (4) obtained some seedlings in May from seed collected the previous August and sown outdoors in January.

Therefore it seemed desirable to learn whether the reported rapid loss of viability was a matter of improper storage, dormancy, or unsuitable temperatures for germination of the stored seed.

PROCEDURE

A few ounces of freshly collected seed of *Angelica archangelica,* (syn. officinalis) was obtained from the Rare Plants Garden, Arcata, California in August 1946. It was dewinged by rubbing and cleaned by screening and fanning until it was of high purity and practically 100 per cent filled.

Portions of the seed were stored as follows: Sealed glass vials packed full and kept at room temperature, full sealed glass vials kept in a mechanical refrigerator where temperature was about 35 degrees F, and in paper packet at room temperature.

On March 23, 1947 duplicate 100-seed samples from each of the storage lots were sown in moist vermiculite and held under the following conditions: controlled temperatures of 42 degrees F for 16 hours, and 77 degrees F 8 hours daily, constant temperature of 77 degrees F, outdoors at Salinas, California, and in a greenhouse. The greenhouse had controlled night temperature of 68 degrees F and day temperatures varying, usually reaching 85 degrees F for a few hours. The prevailing outdoor temperatures were 45 degrees F minimum and 70 degrees F maximum, although a 3-day warm spell occurred during which maximum temperatures reached 90 degrees F during the test.

All of the sowing media were kept liberally supplied with moisture. Counts of the seedlings were made every other day during the emergence period.

RESULTS

Figs. 1 and 2 show the relative speed and percentages of emergence. These characteristics were clearly influenced by the conditions of pre-

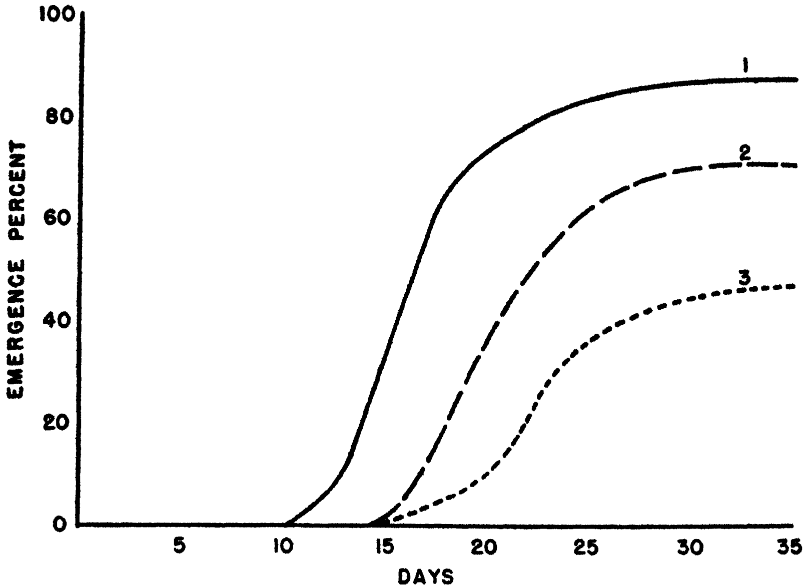

FIG. 1. Curve 1 shows emergence from seed stored sealed at 35 degrees F, 2 is seed stored unsealed at room temperature, and 3 seed stored sealed at room temperature. The three lots were germinated under the same conditions.

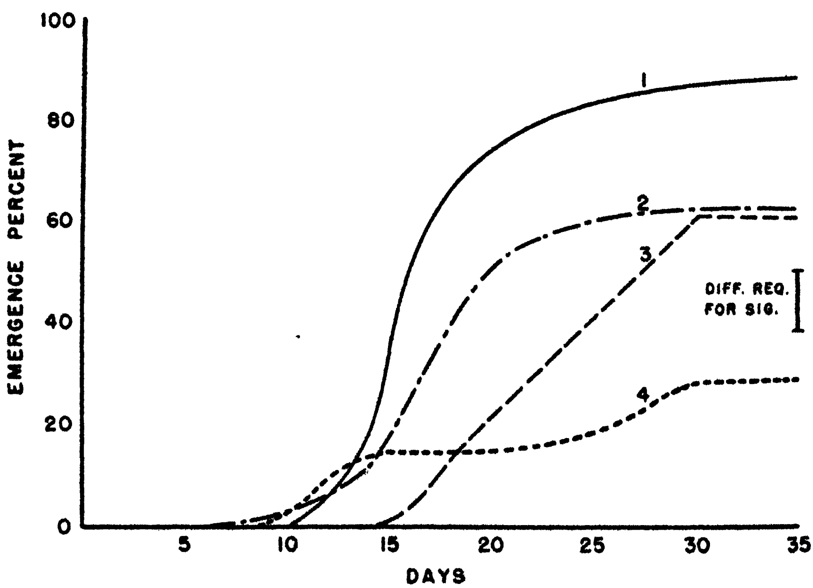

FIG. 2. Emergence from seed stored sealed at about 35 degrees F for 8 months then germinated at different temperatures as follows: 1, alternating 42 to 77 degrees F, 2, greenhouse 68 degrees F nights and 80 to 90 degrees F daytime, 3, outdoors approximately 45 to 70 degrees F, and 4, constant 77 degrees F.

vious storage and by germination temperatures. Table I shows the totals of emergence resulting from the combinations of storage and germination temperatures.

The seed from sealed cold storage germinated more rapidly and in higher percentages at all germination temperatures employed than did seed from other storages and germinated at corresponding temperatures. Open storage at room temperature was second best, and sealed storage at room temperature poorest. Probably the moisture content of the seed contributed to the adverse effect of sealing at room temperature; but the limited supply of seed did not permit moisture determinations nor trial of various moisture contents.

TABLE I—PERCENTAGES OF SEEDLINGS OBTAINED FROM SEEDS STORED UNDER DIFFERENT CONDITIONS AND GERMINATED AT VARIOUS TEMPERATURES

Storage Condition for Eight Months	Germination Temperatures				Means for Storage
	Controlled 42 to 77 Degrees F	Constant 77 Degrees F	Outdoors 45 to 70 Degrees F	Greenhouse 65 to 85 Degrees F	
Open storage at room temperature	71.0	10.5	39.5	31.0	38.0
Sealed storage, room temperature	47.5	6.5	20.0	6.5	20.1
Sealed storage, at 35 degrees F	88.0	28.5	60.5	56.0	58.2
Means of lots having same germination temperature (per cent)	68.8	15.2	40.0	31.2	

Germination temperatures strongly influenced germination of all storage lots. The daily range of 42 to 77 degrees F was best. This is not surprising since the plant is native to northern Europe where nights are cold and days warm in the spring season.

An interesting effect of the 77 degrees F constant temperature appears in the atypical germination curve. Of the total number of seeds germinating at this temperature, about half of them germinated promptly and the other half at a later period. While the graph shows only the samples from cold storage and germinated at this temperature, the lots from other storage conditions exhibited the same behavior with respect to a dual emergence period.

SUMMARY

Seed of *Angelica archangelica,* (syn. officinalis) may be stored for at least 8 months without serious loss of viability. The best of the storage conditions tried was sealing in a full airtight container held at about 35 degrees F, and the best germinating temperature was 42 degrees F for 16 hours and 77 degrees F for 8 hours daily.

The limited supply of seed confined the experiment to only three conditions of storage, for one period of time, and four temperatures of germination. Further trials would be necessary to establish the practical limits of storage life and optimum temperatures for germination.

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The Flowering Response of the Veitch Gardenia To Long-Day Treatment

By E. W. McElwee,[1] *Alabama Experiment Station, Auburn, Ala.*

The gardenia, used primarily as a corsage flower, is greatly in demand for holiday seasons and winter months. The gardenia blooms in the South under normal greenhouse forcing conditions in the late winter and spring months. Any treatment that will advance the blooming date will increase the value of the blooms, particularly if they are brought into flower for the Christmas season.

A review of the previous work on the Veitch Gardenia reveals a varied response of this plant to photoperiodic treatment. Baird and Laurie (1) found that short-day treatment during the summer was effective in inducing flower bud differentiation and that additional illumination in the late stages of bud development caused buds to open more rapidly. Keyes (2) found that supplementary illumination increased the number of buds formed and increased production when a 70 degree F temperature was maintained during the long-day period, followed by a 60 degrees F temperature during the subsequent short-day period. The author (3) found that additional illumination beginning September 15 or October 1 was effective in inducing flowering during December, an average of 74 days earlier than plants grown under normal conditions. Post (4) states that photoperiodic treatments are probably of little value in forcing early flowering in the gardenia and that additional illumination should not be used unless needed to stimulate the growth of well-developed buds.

Procedure

A preliminary test in 1939 with 3-inch plants transplanted to the greenhouse August 26, given various long-day treatments, and later grown in a cool house at approximately 50 degrees F, indicated that additional illumination significantly advanced the blooming date of the Veitch Gardenia without affecting the quality and total production of blooms. The long-day treatment from October 1 to February 5 advanced the blooming date 40 days, or from May 22 to April 12. The small plants in this preliminary test did not show marked vegetative growth and did not respond to long-day treatment until the warm days of late winter and early spring, indicating that older or more mature plants grown at a higher temperature might show a greater response to long-day treatment.

Forty-five plants spaced 12 by 12 inches apart were used in two series of treatments. Long-day treatment consisted of lighting from 5:00 p m to 10:00 p m daily with 100-watt Mazda lamps spaced 5 feet apart lengthwise over the center of a 42-inch growing area and 24 inches above the plants.

In 1940 2-year cut-back plants of Veitch Gardenia were trans-

[1]At present a member of the staff of the Mississippi Agricultural Experiment Station, State College, Mississippi.

planted from the lath house to ground beds on August 15 and later grown at approximately 60 degrees F. Twenty plants were given additional illumination from September 15 to February 5, October 1 to March 1, and November 15 to March 1.

In 1941 plants from 4-inch pots were transplanted to a raised bench on June 15 and grown at 60 degrees F. Twenty-five plants were given additional illumination from September 1, September 15, and October 1, respectively to April 1.

The results obtained from the two series of treatments are given in Table I.

TABLE I—RESPONSE OF VEITCH GARDENIA TO ADDITIONAL ILLUMINATION AT 60 DEGREES F

Additional[1] Illumination Beginning	Age of Plants	No. Plants Per Treatment	Effective Blooming*		Maximum Blooming Period		Yield of Blooms		Average Diameter of Bloom
			Date	No. Days Advanced	Date	No. Days Advanced	Total	Per Square Foot	
Check	1-year	25.0	Feb 28	0	Mar 15-30	0	194	7.8	1.9
	2-year	19.0	Feb 20	0	Apr 15-30	0	187	9.8	1.8
	Ave	22.0	Feb 24	0	Apr 1-15	0	191	8.8	1.9
Sep 1	1-year	25.0	Nov 28	90	Dec 15-30	90	219	8.8	2.2
Sep 15	1-year	25.0	Nov 10	108	Dec 1-15	105	280	11.2	2.1
	2-year	20.0	Dec 16	65	Jan 15-30	89	260	13.0	1.7
	Ave	22.5	Nov 29	87	Dec 23–Jan 7	97	270	12.1	1.9
Oct 1	1-year	25.0	Dec 12	76	Dec 15-30	90	291	11.6	2.1
	2-year	20.0	Jan 6	44	Jan 15-30	89	261	13.1	1.6
	Ave	22.5	Dec 26	60	Jan 1-15	90	276	12.4	1.9
Nov 1	2-year	20.0	Jan 6	44	Jan 15-30	89	122	6.1	1.5

*Date when flowering averaged at least one-half bloom per plant.

DISCUSSION OF RESULTS

Plants receiving additional illumination beginning September 15 and October 1 consistently produced more blooms per square foot than either untreated plants or plants receiving earlier or later treatment. Plants given additional illumination beginning September 15 and October 1 produced an average of 39 per cent more blooms than untreated plants and plants receiving additional illumination from September 1 and about 100 per cent more than plants receiving additional illumination from November 1. The September 1, September 15, and October 1 treatments were about equally effective in bringing 1-year plants into maximum bloom for the Christmas season. The data indicate that 2-year plants should be given additional illumination earlier than September 15 to induce maximum bloom during December, since plants receiving additional illumination September 15 reached effective bloom by December 16 but did not produce maximum bloom until late January.

Additional illumination during the later stages of growth was progressively less effective in advancing the average effective blooming

dates of the plants. However, it was about as effective in advancing the maximum blooming period. Additional illumination treatments beginning September 1, September 15, October 1, and November 1 advanced the average effective blooming date 90, 87, 60, and 44 days, respectively, while each of these treatments advanced the average maximum blooming period approximately 90 days.

Summary

Additional illumination beginning about September 15 was effective in bringing the 2-year-old Veitch Gardenia plants into bloom, under southern conditions, for the Christmas season. Maximum bloom came after Christmas when additional illumination was started September 15.

The September 1, September 15, and October 1 treatments were about equally effective in bringing 1-year plants into maximum bloom for the Christmas season.

Plants receiving additional illumination beginning between September 1 and November 1 reached maximum bloom approximately 90 days earlier than untreated plants.

Additional illumination beginning September 15 and October 1 increased bloom production over that of earlier or later treatment.

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Interrupted Shading of Chrysanthemums

By D. C. Kiplinger and John Alger, *Ohio Agricultural Experiment Station, Wooster, Ohio*

The object of most applied research in the field of floriculture is to obtain greater yields of a high quality product at the same or less cost than the usual commercial method. One of the problems confronting the chrysanthemum grower is to increase production per square foot without reducing the quality. With this as a basis, several treatments which are described were used on eight varieties of chrysanthemums.

1. Multiple pinch — rooted cuttings benched 8 by 8 inches June 6, pinched June 18 retaining three stems per plant, pinched again August 8 retaining three stems per stem (nine per plant), and shaded August 20.
2. Early pinch — three stems per plant. Rooted cuttings benched 8 by 8 inches June 6, pinched June 15, and shaded August 1.
3. Interrupted shading — one stem per plant. Rooted cuttings benched 6 by 6 inches June 6, pinched June 15, first shading July 3 to July 10, long day exposure July 11 to August 1, and shaded August 1.
4. Interrupted shading — two stems per plant. Same procedure as for No. 3 except benched 8 by 8 inches.
5. No pinch — rooted cuttings benched 6 by 6 inches June 6, and shaded August 1.
6. Time pinch — three stems per plant. Rooted cuttings benched 8 by 8 inches June 6, pinched July 1, and shaded August 7.

The purpose of each of the methods described was to determine which would be the most satisfactory to obtain the desired results. The multiple pinch (No. 1) allowed sufficient time between pinches for growth of three vigorous shoots so that following the second pinch, nine stems of reasonable uniformity would develop. The early pinch (No. 2) assumes that the plants might develop a crown bud and branch of their own accord, resulting in numerous stems per plant. The interrupted shading (Nos. 3 and 4) induces a flower bud to form during the initial shading period, but with a return to long day conditions, numerous side shoots develop and the second shading will set flowers on these shoots. The no pinch (No. 5) assumes that crown buds would be formed and that vegetative shoots would develop around this flower bud. The formation of a crown bud or flower bud surrounded by vegetative shoots is a common phenomenon under long day conditions on chrysanthemums. The time pinch (No. 6) is a standard commercial practice which regulates the spray formation on pompons and eliminates crown buds on standard chrysanthemums. It served as a check for comparison of the various treatments with the usual commercial production techniques.

The varieties used and their normal maturity dates are listed in Table I. The plants were given the usual commercial handling in regard to watering, fertilizing, pest control, and so on. Black sateen

cloth was used for shading, being applied from 5 p m to 7 a m, and on the August shading it was continued until flower buds showed color. The side buds on varieties grown as disbuds were removed so that one flower was retained per stem. On pompon types all side shoots were removed that did not contribute to the flower spray. Fifty plants of each variety were grown in each plot.

The results of the various treatments are shown in Table I and the results are expressed in the number of commercially acceptable stems per plant.

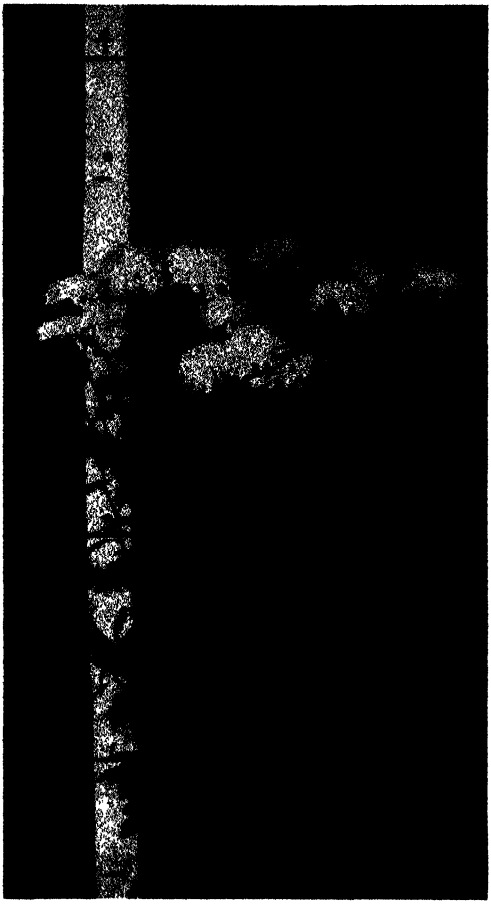

FIG. 1. Effect of interrupted shading on Little America, two-stems per plant.

The data show that of the various treatments, the multiple pinch (No. 1) and interrupted shading with two stems per plant (No. 4) were most consistent in high production. In this instance the production of two of the pompon varieties was high in the early pinch (No. 2), but the method is not as reliable as either the multiple pinch (No. 1) or interrupted shading (No. 4). The quality on the two treatments, No. 1 and No. 4, was, in general, superior to all other treatments except the time pinch (No. 6) which was only very slightly superior despite the fewer stems per plant. Although the multiple pinch system appears to be a suitable method of production, it has a serious disadvantage. Considerable disbudding of the plant is necessary after the first and second pinch to prevent too many shoots from developing. Allowing too many shoots to develop will reduce the quality of each flower. It has been a common observation in our work as well as in commercial greenhouses that shoots developing from a pinch are not as vigorous as shoots which develop below a crown bud. The purpose of interrupted shading is to induce artificially the formation of a flower bud and then by exposure to a long day arrest the

TABLE I—THE EFFECT OF VARIOUS METHODS OF GROWING ON THE NUMBER OF COMMERCIALLY ACCEPTABLE STEMS PER PLANT ON SEVERAL CHRYSANTHEMUM VARIETIES

Variety	Normal Maturity	Multiple Pinch (No. 1)	Early Pinch (No. 2)	Interrupted Shading One Stem (No. 3)	Interrupted Shading Two Stems (No. 4)	No Pinch (No. 5)	Time Pinch (No. 6)
			Grown as Disbuds				
Golden Herald.....	Oct 25	6.8	7.5	8.8	7.0	4.6	3.0
Little America.....	Nov 10	8.2	3.1	4.3	10.3	4.7	3.0
Masterpiece.......	Nov 15	7.3	4.0	2.8	9.5	4.5	2.8
Bronze Masterpiece	Nov 15	8.1	3.8	3.9	9.7	3.6	2.8
			Grown as Pompons				
Gold Coast........	Oct 25	8.5	7.1	4.2	7.0	4.0	2.5
Pinocchio.........	Oct 25	9.3	13.0	7.5	9.8	9.0	3.0
White Mensa.... .	Nov 11	9.6	11.8	4.8	7.3	4.6	2.7
Sunray.........	Nov 15	*	5.2	6.5	4.6	5.1	2.9

*Not planted.

development of this flower bud and induce growth of the vegetative buds in the axils of the leaves below. In reality it is control over the formation of a crown bud.

Observation of the plants at the time of flowering on the interrupted shading treatment revealed that the earlier a variety matured naturally, the shorter should be the length of the initial shading period. This was particularly noticeable on Golden Herald which matures October 25. The 7-day initial shade induced formation of flower buds in the axils of the leaves as well as the shoot tips resulting in abnormal recurving and "frilliness" of the flower. From this observation on this preliminary test, additional work is under way to determine the length of duration of the initial short day period as well as the subsequent long day period not only on chrysanthemums flowered during the normal fall season but also on chrysanthemums flowered at all seasons of the year.

SUMMARY

Of several cultural treatments given to chrysanthemums to increase production and maintain high quality, the multiple pinch and interrupted shading methods appeared to be best. Of these two methods the interrupted shading is preferable because of the reduced labor required and the possibilities of greater production per square foot.

This preliminary test showed that the length of the initial shading period is critical and must be determined for varieties which mature naturally at various dates as well as for year around flowering of the chrysanthemum.

Considering the interrupted shading method, it appears possible to produce a quantity of long stemmed stock of high quality by increasing the period of long day exposure between the first and second shading. For shorter stemmed stock suitable for packaged flowers where high quality is necessary, this long day period can be reduced, resulting in a product ideally suited for this purpose.

Inheritance of Resistance to Rust in the Snapdragon, Antirrhinum majus[1]

By Gustav A. L. Mehlquist and Rouhollah Rahmani,
University of California, Los Angeles, Calif.

In 1936 it became evident that the highly resistant strains of snapdragons that had been released to the trade three years earlier by the California Agricultural Experiment Station developed considerable rust in certain areas along the Pacific Coast. The appearance of a second form of the rust (*Puccinia antirrhini* D. & H.) was suspected, and in 1937 Yarwood (8) published evidence that this was the case. In 1941 Blodgett and Mehlquist (2) published the results of extensive trials conducted in 1937 and 1938 in an effort to obtain forms of the common snapdragon (*Antirrhinum majus* L.) or other species of Antirrhinum that would be resistant to the second form of the rust. No form of *A. majus* or species closely related to it was found to be immune to this rust, but two species of the majus section, *A. Ibanjezii* Pan. and *A. sicculum* Ucr. and four commercial lines proved fairly resistant. During the summer of 1939 three populations of 25 plants each from each of these six lines were grown in the field at Berkeley. Each population of 25 plants constituted the self progeny of an individual plant selected the previous year. The results confirmed those obtained in 1938. That is, all lines had some rust, but not sufficient to interfere with normal flowering and seed production. That the results were comparable to those of previous years was indicated by the fact that all plants of non-resistant lines were so badly infected that few flowers and no seed were obtained. Plants of lines that were known to be resistant to form 1 of the rust became generally infected, but did flower and produced a fair amount of seed, though usually not of good quality.

Somewhat lower virulence seems to be a characteristic of form 2. The plants became generally infected, but were rarely killed until a fair amount of seed had been set. Apparently the ripening of the seed, coupled with a general infection of rust, was too much for the plants. If but a limited number of seed pods was allowed to mature, the plants frequently reached a second flowering stage.

One plant in one of the three populations grown of a line obtained from Professor Ray Nelson at Michigan State College proved better than the rest. During the whole season it developed very few rust sori, and it grew somewhat more vigorously than the other plants of the line. Cuttings made from this plant proved equally resistant the next year, both in Berkeley and Los Angeles. Seedlings from it varied somewhat in resistance, but in two generations true-breeding lines that were uniformly highly resistant were obtained. In testing these lines for homozygosity of resistance a minimum of 75 plants was used. This was on the assumption that if a heterozygous plant were by

[1]As Mr. Rahmani has returned to Iran, his native country, this paper was written entirely by the senior author, now at the Missouri Botanical Garden, St. Louis, Missouri. However, all the work reported in this paper was done at the University of California.

chance selected, and resistance were controlled by two genes, at least one double recessive would be obtained, with a probability of 99 in 100. The number 75 was fixed after calculating *n* from the equation

$$1-\left(\frac{15}{16}\right)^n=\frac{99}{100}, \text{ which is about 71.}$$

This resistant line was a magenta-flowered, dwarf, bedding type. In the nomenclature of the seedsmen it was of the *nanum grandiflorum* type. Because of its magenta color which is the top-dominant color in Antirrhinum (1, 7), but the least desirable from a horticultural point of view, it was crossed to several different kinds that were more desirable horticulturally but for the most part without any resistance to rust. Some 3000 F_1 plants were grown in 1943, comprising somewhat over 100 crosses. Three years earlier, crosses had been made between *Antirrhinum Ibanjesii* and various majus forms but, although the F_2 and F_3 populations totalled more than 5000 plants, no segregate combining high resistance with the appearance of a desirable majus type was obtained. Back-crosses to the majus lines were made, but the effects of the war necessitated practically closing the project at the end of 1943.

In 1944 and 1945 Mr. Rahmani, then a graduate student, grew a few hundred plants, mostly F_2 and BC_1, from the 1943 crosses in order to get further data on the inheritance of resistance. The reason for wanting more data on the inheritance of resistance was twofold: first, no data relative to the genetics of resistance of the second form of the rust had been published; and, second, it had been noted in 1943 that considerably more rust appeared on F_1 populations between highly resistant and susceptible lines than would be expected from the data published by Emsweller and Jones (4), who found resistance to be quite dominant. For comparison additional F_1 plants were grown for each F_2 and BC_1.

Although Mains (5) and Doran (3) agree that the optimum temperature for spore germination of this rust is around 50 degrees F, our experience in California has been that the rust caused the greatest damage when night temperatures were 60 degrees F or above. This was also reported for the Chicago area by Peltier (6). For this reason and because of the fact that more space was available in that section where 60 degrees night temperature was maintained, all the inoculations made in the greenhouse were at this temperature. The inoculations made in the cold frame and field were at natural temperatures varying from 50 to somewhat over 60 degrees F at night. The day temperatures under all conditions were considerably higher.

The inoculations were accomplished by spraying vigorous seedlings about 10 weeks old with a spore suspension made by washing heavily infected plants in water. Plants both non-resistant and resistant to form 1 of the rust but not to form 2 were used. No plants were available that were known to be resistant to form 2, but not to form 1. The spore suspension was applied late in the afternoon by means of a watering can equipped with a fine rose, and then the plants were cov-

ered with newspaper which was kept on until next morning. After that the plants were sprinkled daily, late in the afternoon, with water.

In the field under these conditions the non-resistant lines became so heavily infected that they died before reaching the flowering stage. A fair amount of rust developed on the F_1 plants and even the resistant lines developed more rust than had been seen on them previously, but they did not in any way appear to be slowed down by the rust. In a separate block where plants of the resistant parent lines were alternated with non-resistant plants, but not inoculated nor sprinkled overhead, the resistant lines did not show more than an occasional sorus although the non-resistant plants were killed by the disease.

In the greenhouse, where the plants were maintained only 4 weeks after inoculation, the F_1 and resistant parent lines developed somewhat less rust, whereas the non-resistant lines developed almost as much as in the field. For lack of space most of the F_2 and BC_1 populations were grown in flats in the greenhouse only until ready for inoculation. They were then transferred to a cold-frame and inoculated in the same manner as the plants in the field. Plants of the parent lines and F_1 plants were included for comparison. The F_1 plants in this experiment were grown from the same lots of seed that produced the F_1 plants in 1943 and which were self-pollinated and back-crossed to

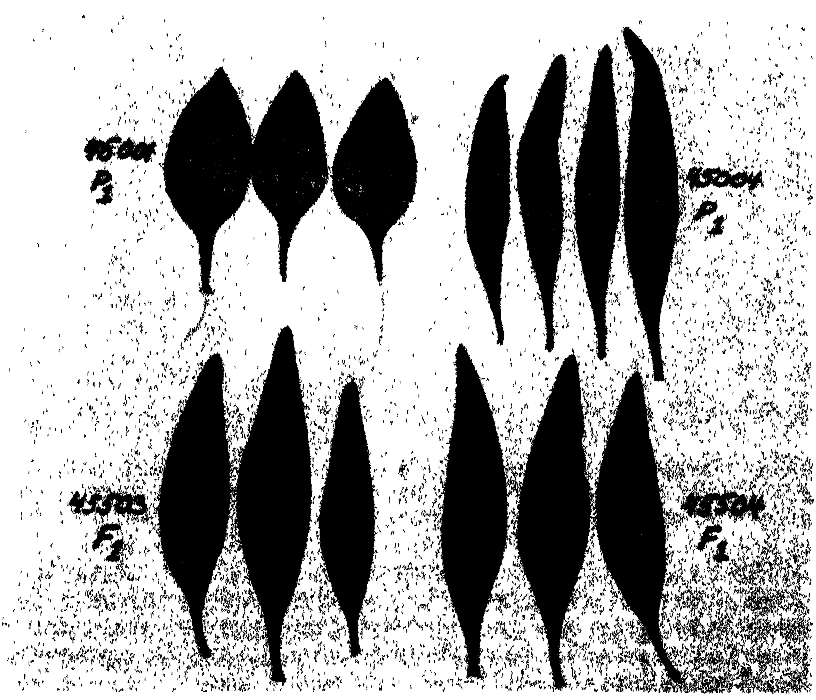

FIG. 1. 45001, non-resistant parent with "heavy" infection. 45004, parent resistant to both forms of rust showing "light" infection. 45503 and 45504 are leaves from F_1 plants showing "medium" infection.

produce the seed for the F_2 and BC populations. The infection obtained in the cold-frame was more severe than that in the greenhouse, but not quite so severe as that in the field.

Figs. 1 and 2 show the amount of rust obtained in the field in 1945. The lack of clear dominance is evident. In fact, the F_1s come close to being intermediate. This is particularly striking in Fig. 2 showing the behavior of form 2 of the rust. On the other hand, the F_1 involving both forms of the rust (Fig. 1) is closer to the resistant parent as far as total infection goes. These results indicate that the gene controlling resistance to the second form of the rust is not a dominant one, but expressing its effect directly in proportion to dosage, whereas the gene for resistance to form 1 is partially dominant.

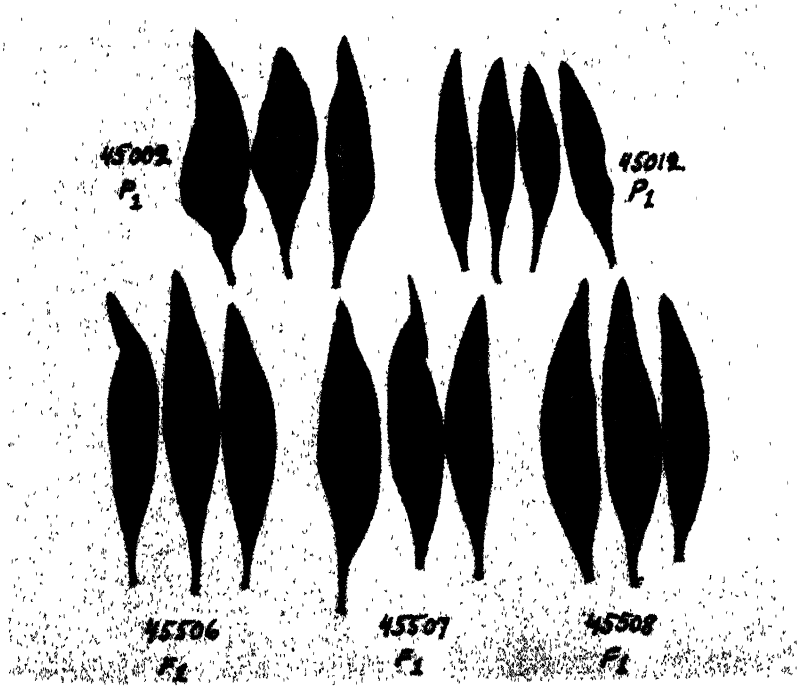

FIG. 2. 45002, parent resistant to form 1, but not to form 2 with "medium" infection. 45012, parent resistant to both forms of rust with "light" infection. 45506, 45507, 45508 are from F_1 plants, all with "medium" infection.

The F_2 and backcross data summarized in Table I, though based on small populations, support this hypothesis and furthermore indicate that only two genes are involved; that is, one for each form of rust. To facilitate discussion, the designation R_1 and R_2 representing resistance to forms 1 and 2 respectively, will be used.

In evaluating cross 1, it has been assumed that only the genotypes $R_1R_1R_2R_2$ and $R_1r_1R_2R_2$ would provide sufficient resistance to the rust to permit only light infection. The genotype $R_1R_1R_2r_2$ would not

TABLE I—SUMMARY OF F_2 AND BACKCROSS DATA

	Description of Crosses	Infection			
		Light	Medium	Heavy	Total
1	Susceptible × resistance to form 1 and 2....	27*	60	29	116
2	Resistance to form 1 × resistance to form 1 and 2	27*	56	44	127
3	Back cross of cross 1 to susceptible....	—	14	46	60
4	Back cross of cross 2 to susceptible ..	—	28	25	53

*The lightly infected plants were fairly distinct as a group. On the other hand, there was no clear cut difference between the "mediun" and "heavy" groups.

be likely to give such high resistance because of the lack of dominance of the R_2 gene. On this basis three-sixteenths of the progeny, or 22 plants, should be highly resistant. Actually, 27 plants were classified as such, which number does not differ significantly from the expected ($\sigma = 4.2$). In cross 2, where only the R_2 gene is involved, only those plants that are homozygous for this gene, or one-fourth of the progeny, should be expected to show high resistance. The number actually classified as such does not differ significantly from the expected $\left(\frac{a}{\sigma} = 1.+\right)$. Because in crosses 1 and 2 the lightly resistant plants as a group were more distinct than the "medium" or "heavy" groups, it has been considered more accurate to compare the proportion of them to the total rather than to compare all three groups at once.

The back-cross populations being composed of fewer genotypes are consequently somewhat easier to interpret. In cross number 3 four genotypes should be expected, namely, $R_1r_1R_2r_2$, $R_1r_1r_2r_2$, $r_1r_1R_2r_2$, and $r_1r_1r_2r_2$. Of these, only $R_1r_1R_2r_2$ has been considered to have sufficient resistance to permit medium infection only. All the plants representing the other genotypes should become heavily infected. The data agree with this assumption. In cross number 4 two genotypes only are involved, namely, $R_1R_1R_2r_2$ and $R_1R_1r_2r_2$. On the assumption stated above that infection by form 2 is proportional to the dosage of the gene R_2, half the plants should show medium and the other half heavy infection. The data from cross 4 agree with this assumption.

Despite the comparatively small number of plants involved, it seems safe to conclude that two genes only are involved. The designations R_1 to indicate the gene for resistance to form 1 of the rust, and R_2 to indicate the gene for resistance to form 2 is suggested.

It is unfortunate that this work had to be so severely curtailed due to the war, for there are several problems that should be investigated further. In the first place, an effort should be made to separate the two forms so that the effect of either on the host could be studied independently. It is quite possible that the requirements for optimum growth of the two forms differ. The fact that at the time of this study, the second form had successfully invaded the coastal areas from central California down to San Diego but not, as far as we are aware, into the warmer interior valleys might indicate that the coastal climate is more suitable for its development. However, other areas outside the State of California may prove suitable.

When the senior author moved to St. Louis in 1945, it was ex-

pected that this study could be continued, but the climate of St. Louis has not proved favorable for rust studies out-of-doors and, because non-resistant snapdragons have had to be grown in the greenhouses for other purposes, it has not seemed advisable to attempt any rust studies.

The question has been raised by seed producers as to whether F_1 hybrids would be sufficiently resistant to rust to make the production of hybrid seed economically feasible. Although hybrid snapdragons are gradually winning favor with producers of cut flowers under glass, in view of the lack of clear dominance of the gene for resistance to form 2 of the rust and the fact that with better cultural and control practices losses from rust infection under glass are becoming negligible, it would appear that the answer is no. For out-of-door production in milder areas and for home gardening generally, however, the incorporation of resistance to both forms of rust seems to be the only dependable solution of the problem.

Summary

Evidence is presented showing that form 2 of the snapdragon rust *Puccinia antirrhini* D. & H. is controlled by a single partially dominant gene. The designation R_2 for this gene, and R_1 for the gene previously described by Emsweller and Jones controlling resistance to form 1 is suggested.

Because of the R_2 gene being only partially dominant, resistance in the F_1 cannot be depended on as any real help in controlling rust on plants being grown from hybrid seed under conditions favorable to the rust.

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Effect of Nitrogen and Potash Fertilizers on Patrician Carnations in Soil

By George Beach and August Mussenbrock, *Colorado A. & M. College, Ft. Collins, Colo.*

This experiment was planned to compare the effects of five different nitrogen levels on the yield of carnations in soil. Two levels of potash also were compared in the same plots to see if a relatively high potash level would offset the effect of high nitrogen.

Materials and Methods

Two center benches side by side in the same greenhouse were used. Each bench was 5 feet by 35 feet and was partitioned into 10 plots. Double boards were used to prevent fertilizer treatment of one plot influencing adjoining ones. Treatments included five levels of nitrogen with four replications and two levels of potash superimposed on the nitrogen treatments, making duplicate plots of each of 10 different treatments. Random arrangement of plots was used as follows:

Plot Arrangement — Planned Levels Nitrogen/Potash (Parts Per Million)

0/60	0/0	60/60	100/0	40/60	20/0	100/0	60/0	20/60	100/60

40/0	60/0	20/60	0/60	40/0	100/60	0/0	20/0	40/60	60/60

The soil was steamed in April and 5 pounds of treble superphosphate per 100 square feet of bench space was worked into all 20 plots before planting. Thirty-five plants of the Patrician variety were planted in each plot on June 20th. Surface hand watering was used throughout the cropping season. Sodium nitrate and potassium chloride were applied in liquid form six times between August and April to raise the nitrate tests of plots testing lower than the amounts shown in the diagram above. The Spurway soil test method was used.

TABLE I—Average Tests Nitrogen/Potash of Duplicate Plots — Parts Per Million (Nitrogen is NO_3 on Extract Basis —Spurway Tests Used Throughout)

Planned	Jul 12	Aug 12	Sep 12	Oct 12	Nov 21	Jan 18	Feb 28	Apr 15	Actual Average for Season
0/0	45.0/5.0	17.5/6.0	7.0/6.0	30.0/0	11.0/15.0	1.0/1.0	0.5/0	0/0	14.0/4.1
0/60	37.5/6.0	17.5/5.0	6.5/19.0	9.0/2.5	25.0/15.0	0/6.0	0/11.0	0/0	11.9/8.0
20/0	50.0/5.0	42.5/7.5	14.0/9.0	45.0/3.5	13.5/10.0	0/2.0	1.5/0	0/0	20.8/4.6
20/60	50.0/8.5	45.0/8.5	15.0/15.0	4.5/3.5	3.5/20.0	1.0/7.5	0/5.0	0/2.5	14.9/8.8
40/0	50.0/7.5	32.5/8.5	29.0/9.0	42.5/1.0	7.0/7.5	5.0/0	0/0	0/0	20.8/4.2
40/60	55.0/7.5	55.0/8.5	27.0/15.0	75.0/5.0	45.0/10.0	5.0/6.5	1.0/4.0	1.0/0	33.0/7.0
60/0	40.0/8.5	42.5/8.5	35.0/7.0	45.0/2.5	13.5/20.0	0/1.0	22.5/0	2.5/0	40.3/6.0
60/60	40.0/7.5	45.0/10.0	37.5/16.0	22.0/3.5	32.5/10.0	5.0/5.0	11.0/10.0	2.0/2.5	24.4/8.0
100/0	47.5/7.5	60.0/7.0	35.0/16.0	27.0/2.5	75.0/10.0	5.0/0	11.5/5.0	6.0/0	33.4/6.0
100/60	50.0/7.5	50.0/13.5	37.5/19.0	35.0/5.0	150.0/150	2.5/5.0	29.0/3.5	3.5/2.5	44.7/8.9

After each soil test, the amount of sodium nitrate was calculated which, disregarding losses, would bring the tests up to 20, 40, 60, and 100 ppm respectively. The nitrate was then dissolved in water and applied to the plot surface. The amount of postassium chloride was similarly calculated to raise the test to 60 ppm. Table I gives average soil tests for duplicate plots.

Flowers were cut separately for each plot and a record was kept of the number of flowers and the stem length in centimeters. All plants of each plot were used for the yield figures.

Results

Five thousand two hundred and eighty-four flowers were cut during the season ending June 5, 1947. Table II shows the number of flowers cut per plot and the average stem length.

TABLE II—Yield Data*

Plot No.	Ppm Not to Exceed		Stem Length (Cm)	Number Flowers
	Nitrogen	Potash		
9	None added	—	57.0	218.0
17		—	58.0	107.0
10		60	56.0	196.0
14		60	60.0	208.0
Mean...... ..			57.75	197.25
5	20	—	63.0	269.0
18	20	—	63.0	245.0
2	20	60	65.0	303.0
13	20	60	62.0	254.0
Mean......			63.25	267 75
11	40	—	63.0	289.0
15	40	—	62.0	275.0
6	40	60	64.0	289.0
19	40	60	63.0	256.0
Mean			63.00	277.25
3	60	—	67.0	291.0
12	60	—	62.0	292.0
8	60	60	60.0	277.0
20	60	60	66.0	269.0
Mean			63.75	282.25
4	100	—	67.0	325.0
7	100	—	62.0	277.0
1	100	60	68.0	316.0
16	100	60	61.0	268.0
Mean ...			64.50	296.50

*Experimental mean 62.45 264.20
M.S.D. in stem length .... at 0.05 = 3.85; at 0.01 = 5.40
M.S.D. in number flowers .... at 0.05 = 26.17; 0.01 = 36.69

Discussion

The amounts of fertilizer used would theoretically bring the tests up to the planned levels. But leaching and other losses of available nutrients resulted in lower tests than were originally planned. The average test of duplicate plots, except for one test of 150, never exceeded 75 ppm NO_3. K tests never exceeded 20 ppm.

Analysis of variance in the yields of flowers shows a highly significant increase in yield between fertilized and unfertilized plots. The correlation coefficients for treatments also show almost perfect correlation between number of flowers per plot and longest stems. No significant difference in yield is shown between those plots to which potash was added and the ones where none was added.

There is a continued (though not significant) increase in yield with increased nitrogen applications so that even the highest rate apparently was not too much nitrogen. Hence no conclusion is warranted as to whether a relatively high potash level would offset the effect of too much nitrogen.

The experiment is being repeated this year, using higher rates of fertilizer application.

Summary

Plots with the highest nitrogen test for the season gave a higher yield and longer-stemmed flower than did any of four lower levels of nitrogen. The experiment is being repeated, using heavier fertilizer applications in an attempt to find a damagingly high rate of nitrogen where a comparison can be made of the effect of relatively high potash upon excess nitrogen.

The Incidence of Blindness in the Better Times Rose

By J. R. Kamp, *University of Illinois, Urbana, Ill.*

For many years, producers of greenhouse roses have felt that they were losing a large and valuable part of their potential flower production because not all shoots would terminate in flowers. Shoots not so terminating were designated "blind shoots" and the large number of such shoots noticeable on plants during the winter months has led the commercial grower to consider blindness a major problem.

The present investigation was designed to study the incidence of blindness, particularly on the popular hybrid tea variety Better Times, and to attempt a correlation between this condition, external environment and chemical composition of the stems.

Hubbell (2) and Laurie and Bobula (3) have clearly shown that flower bud initiation begins in all shoots of the hybrid tea rose. Not all of these flower buds reach maturity, however, for early abortion and abscission of many of them give rise to blindness. The belief among growers that this is due to poor light conditions arises from the fact that blindness is quite noticeable on plants during the winter season.

In the present investigation it was assumed that, if blindness was due to a carbohydrate deficiency resulting from low light conditions, it could be increased artificially by shading the plants and also by systematic defoliation. Defoliation, by removing the synthesizing surfaces, should also reduce the hormone supply and a comparison between shaded and defoliated plants should allow a differentiation between carbohydrate and hormone deficiencies. The shaded plants should be deficient in carbohydrates alone while the defoliated plants should be deficient in both carbohydrates and hormones.

Materials and Methods, 1945–46 Season

The work was done during the 1945–46 and 1946–47 seasons in the floriculture greenhouses of the University of Illinois. During the first season, which lasted from June 1945 to May 1946, the effects of defoliation on three varieties of greenhouse rose were noted. Interest was centered not only on the effects of defoliation in general but also on the differences in varietal response. Differences between blind and flowering shoots on check plants were also carefully noted.

Twelve plants of the variety Pink Delight were kept to one leaf per shoot by the removal of a leaf from the base of the shoot every time a new one expanded at the shoot tip. Twelve more plants were kept to two leaves per shoot, and all defoliated plants were compared with 24 check plants with respect to total number of shoots, number of blind shoots, percentage of blindness and general growth.

Twelve Better Times rose plants were defoliated to two leaves per shoot and 12 to three leaves per shoot in the manner described above, and comparisons were again made with 24 check plants of this variety.

Twenty-four check plants of the variety Peters Briarcliff were compared with 12 defoliated to three leaves per shoot and 12 defoliated to four leaves per shoot.

RESULTS, 1945–46 SEASON

Defoliation of any kind greatly reduced apical dominance and produced a great increase in the number of shoots produced. At the beginning of the season, this influence extended to the base of the plants, resulting in a relatively large number of bottom breaks. The 72 check plots (all three varieties combined) produced only one bottom break prior to September 1 in contrast to 27 bottom breaks on the same number of defoliated plants.

Defoliation so greatly increased the number of shoots per plant that (Table I) by the end of the season, the check plants (all three varieties combined) averaged 13 shoots per plant, the defoliated ones 26 shoots per plant. In the case of the variety Pink Delight, to cite a single striking example, check plants averaged eight shoots per plant in contrast to 26 shoots per plant on those defoliated to one leaf per shoot. This increase in the number of shoots produced low twiggy bushes, in marked contrast to the tall plants in the check plots.

TABLE I—TOTAL NUMBER OF SHOOTS PER 100 PLANTS (SEASON 1945–46)

Treatment	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
			Pink Delight					
Check	729	338	613	471	629	479	571	775
1 leaf	950	917	800	1,408	2,092	2,083	2,083	2,608
2 leaves	1,058	817	675	992	1,458	1,292	1,967	2,517
			Better Times					
Check	775	504	683	733	758	929	963	1,517
2 leaves	1,317	742	1,417	708	2,058	1,883	2,483	2,308
3 leaves	1,167	792	1,433	1,292	1,808	2,300	2,375	2,758
			Peters Briarcliff					
Check	904	342	579	683	692	1,050	1,250	1,654
3 leaves	1,067	1,008	908	783	1,167	1,542	1,967	2,508
4 leaves	1,158	900	892	925	1,442	2,150	2,558	2,842

Defoliation also resulted in a striking increase in the number of blind shoots per plant (Table II) and in a very marked increase in

TABLE II—NUMBER OF BLIND SHOOTS PER 100 PLANTS (SEASON 1945–46)

Treatment	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
				Pink Delight					
Check	29	46	63	200	92	271	271	263	296
1 leaf	167	242	853	667	1,200	1,858	1,750	1,808	2,350
2 leaves	217	383	383	475	725	1,183	1,058	1,475	2,083
				Better Times					
Check	75	142	129	342	396	529	617	733	879
2 leaves	333	558	675	908	633	1,642	1,683	2,259	1,933
3 leaves	337	575	892	1,208	975	1,517	1,883	2,109	2,367
				Peters Briarcliff					
Check	71	179	171	313	346	400	742	925	1,029
3 leaves	325	342	475	708	642	1,033	1,258	1,617	2,233
4 leaves	275	342	433	608	500	1,337	1,625	1,892	2,525

the percentage (Table III) of blindness. Check plants of the variety Pink Delight had 38 per cent blindness while there was 90 per cent blindness on those plants defoliated to one leaf per shoot.

Although defoliation increased the total number of shoots, the number of blind shoots, and the percentage of blindness on all varieties, the effects were not always proportional to the amount of defoliation.

TABLE III—PERCENTAGE OF BLINDNESS ON ROSE PLANTS (SEASON 1945–46)

Treatment	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
				Pink Delight				
Check	6.28	18.52	32.65	19.47	43.05	52.00	45.99	38.58
1 leaf	25.44	63.64	83.33	85.21	88.84	84.00	86.80	90.10
2 leaves	36.22	46.94	70.37	73.11	81.14	81 94	75.00	82.78
				Better Times				
Check	18.28	37.78	50.00	53.98	69.78	66.37	76.19	57.97
2 leaves	42.40	75.00	82.58	89.41	79.76	89.38	90.94	83.75
3 leaves	49.28	88.43	85 29	75.48	83.87	81 88	88.77	85.80
				Peters Briarcliff				
Check	19.82	33.88	53 96	50.61	57 83	70.75	74.00	62 22
3 leaves	32.04	60 00	87.16	81.91	88 57	81 62	82 20	89.04
4 leaves	29.50	58.43	68 22	54 54	94.80	75.58	73.94	88.86

A study of the check plants revealed that their flowering shoots averaged twice as many leaves per stem as did their blind ones regardless of season or variety (Table IV).

The results were so similar with each of the three varieties studied that the second season studies were confined to the variety Better Times.

TABLE IV—AVERAGE NUMBER OF LEAVES PER SHOOT ON CHECK PLANTS (SEASON 1945–46)

Variety	Condition	Sep	Jan	Feb	Mar	Apr	May
Pink Delight	Blind	4.14	2.68	1.32	3.29	3.06	2.51
Better Times	Blind	3.83	2.57	3.14	2 44	2.50	2.67
Peters Briarcliff	Blind	3.65	2.78	2.84	2.68	2.56	2.39
Pink Delight	Flowering	9.09	7.47	6.60	8.41	8.34	7.74
Better Times	Flowering	7.95	7.52	8.26	7.51	7.17	6.71
Peters Briarcliff	Flowering	7.63	7.18	8.24	8.25	6.96	6.88

A few preliminary chemical studies near the end of the first season showed that, regardless of variety, rose stems bearing opening flowers had a high concentration of free reducing substances and total sugars in the inch of stem just under the receptable. The concentrations of these substances dropped rapidly, reached a minimum about 3 inches from the flower, then increased very slightly. There was practically no change in concentrations of these substances below a point about 6 inches from the flower.

Mature blind stems showed no marked gradient of either free reducing substances or total sugars. The actual amounts of these substances present were much smaller than in mature flowering stems.

MATERIALS AND METHODS, 1946–47 SEASON

New budded Better Times rose plants were set in the bench on June 15, 1946 and treated in accordance with the following plan. Plants were spaced four across the bench (10 inches apart) with 14 inches between the rows. There were 10 rows to each plot.

Plot 1. Check
Plot 2. Defoliated to four leaves
Plot 3. Shaded
Plot 4. Defoliated to two leaves
Plot 5. Shaded
Plot 6. Check
Plot 7. Defoliated to two leaves
Plot 8. Defoliated to four leaves

Shading and defoliation were begun July 1. Shading was done with a single thickness of heavy cheesecloth that reduced the illumination 50 per cent on cloudy days and 30 per cent on sunny days. Records were taken until May 1947.

Of the 10 rows in each plot, four were used to determine the number of shoots of various kinds, the number of leaves per shoot, and similar data. The other six rows furnished material for chemical analyses.

A large part of the work during the second season took the form of chemical analyses. On October 15, 1946, analyses were made of stems bearing opening flowers, stems bearing buds showing color, stems bearing small buds (about the size of a pea), and very small shoots 1 inch, 2 inches and 3 inches in length. In preparation for analysis, these stems were completely defoliated. Flowers or buds were removed just at the base of the receptacle. Stems were then cut into 1- or 2-inch segments, weighed, dried in a forced draft oven at 75 degrees C, weighed again, and then ground to a fine powder in a Wiley mill.

This dried powder was then analyzed for free reducing substances, total sugars and hemi-reserve carbohydrates, total nitrogen and protein nitrogen.

Total nitrogen was determined by the micro-kjeldahl method. To determine protein nitrogen, 30 to 50 milligrams of the dry tissue was leached five times with hot water using 5 cc of hot water per leaching. To the leachate was added 5 cc of concentrated neutral lead acetate in order to precipitate the water-soluble proteins. The precipitate was filtered off, combined with the original insoluble material, and analyzed as for total nitrogen.

Total sugars were determined as suggested by Heinze and Murneek (1). Reducing sugars were determined by the Shaffer-Somogyi method but since the values sometimes exceed the values for total sugars, the fraction was considered as free reducing substances rather than reducing sugars only.

The residue from the extraction of the sugars was digested with dilute acid according to Murneek's instructions for hemi-cellulose determinations (1) and called "hemi-reserve carbohydrates". It is roughly comparable to a total of starch and hemi-cellulose.

In addition to the sampling of October 1946, 1-, 2- and 3-inch shoots and stems bearing small buds were also collected and analyzed on December 15, 1946 and February 15, 1947. At all these sampling dates, shoots were separately collected from each treatment and from check plots.

At the end of the season, many very immature shoots were collected for examination. All of these shoots had young leaves still folded about the tip so that these leaves had to be removed before it could be seen whether the shoots were blind or flowering. These were called "shoots just recognizable as blind or flowering". They were separated on the basis of presence or absence of buds, dried and analyzed. All shoots about which there was any question were discarded. This sampling completed the work of the second season.

Results, 1946–1947 Season

As in the previous season, any defoliation greatly increased the number of shoots per plant (Fig. 1). This season the increase was proportional to the amount of defoliation. There was also an increase in the number of blind shoots per plant and the total number of shoots on the defoliated plots (Tables V and VI). Shading, however, resulted in no increases in number of blind shoots, in total number of shoots or percentage of blindness.

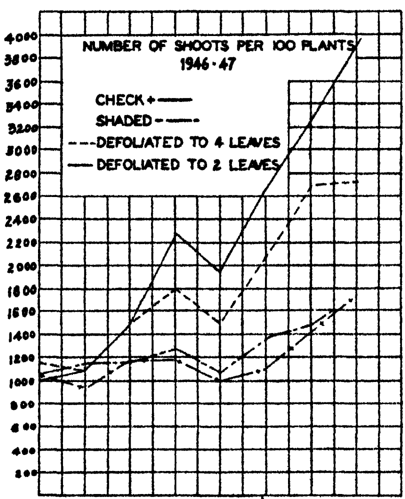

Fig. 1. Number of shoots produced during the 1946–47 season (100 plant basis) on rose plants receiving various treatments.

As in the previous season, flowering shoots bore approximately twice as many leaves per shoot as blind ones, but shading had no effect on the foliation of either blind or flowering shoots. Flowering shoots had an average of approximately seven leaves per shoot throughout the season. This is clearly shown in Fig. 2.

Although the number of blind shoots was increasing throughout the season, analytical data

TABLE V—Number of Blind Shoots on Better Times Rose Plants (Season 1946–47, 100 Plant Basis)

Treatment	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Check	516	538	800	756	694	816	947	1,128
Shaded	503	606	797	881	728	1,047	1,081	1,234
4-leaf	616	684	1,025	1,281	1,084	1,681	2,191	2,047
2-leaf	506	616	1,031	1,734	1,341	2,000	2,831	3,497

TABLE VI—Total Number of Shoots on Better Times Rose Plants (Season 1946–47, 100 Plant Basis)

Treatment	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Check	1,034	950	1,156	1,188	997	1,100	1,441	1,725
Shaded	1,019	1,125	1,134	1,291	1,056	1,362	1,491	1,703
4-leaf	1,153	1,078	1,472	1,809	1,491	2,019	2,703	2,716
2-leaf	997	1,081	1,462	2,306	1,944	2,647	3,234	3,916

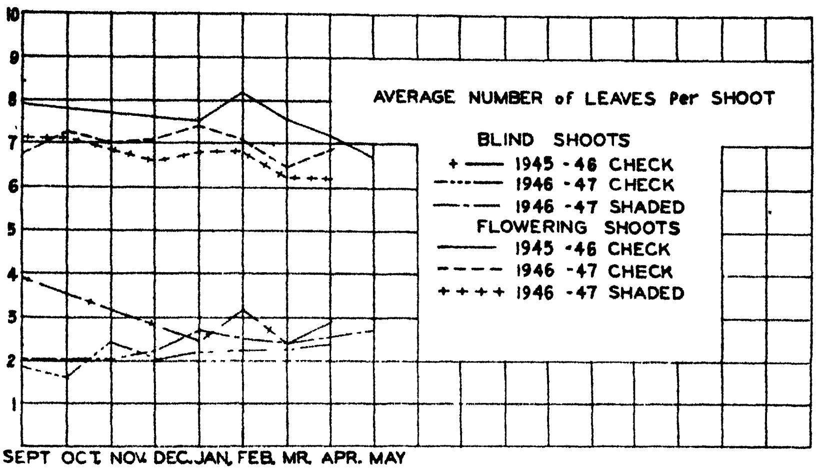

Fig. 2. Average number of leaves per shoot on rose plants growing in open benches and under cheesecloth shade.

from the samplings of October, December and February followed no definite trend. There was, in general, some increase in free reducing substances and total sugars throughout the period, but there were numerous exceptions to the general trend. Nitrogen fractions also increased somewhat as the season progressed. In no case did there seem to be any significance in the concentrations of hemi-reserve carbohydrates. Tables VII, VIII and IX are typical of the analytical data and give some idea of the magnitude of the values determined.

Although there were changes throughout the season in the maximal and minimal amounts of the various carbohydrate and nitrogen fractions in the stems, certain gradients appeared to be characteristic of certain types of stems at various stages in their development. It should be noticed that mature flowering stems had their greatest concentration of free reducing substances and total sugars just under the flower. Less developed shoots had similar concentrations near the midpoint of the shoot. Very small shoots had their greatest concentrations near their bases. This seemed to be true for a great many samples taken over a considerable period of time. The differences in composition of mature, blind and flowering shoots is clearly shown in Fig. 3.

Analyses of those shoots just recognizable as blind or flowering were strikingly similar. Although the concentration of carbohydrates was slightly greater in the flowering stems than in the blind ones, the

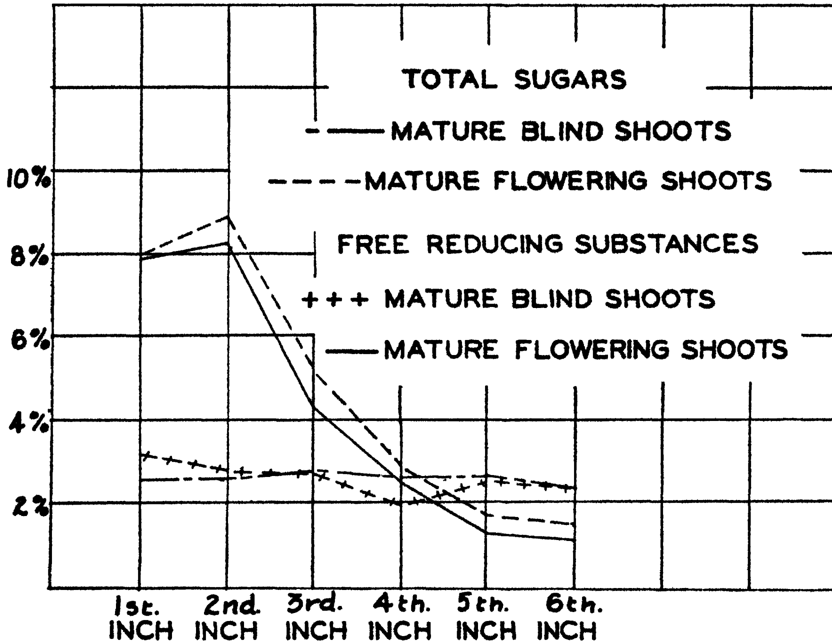

FIG. 3. Chemical composition (free reducing substances and total sugars) of mature blind and flowering rose shoots expressed as percentage of dry weight.

TABLE VII—PERCENTAGE COMPOSITION OF MATURE BLIND SHOOTS FROM BETTER TIMES ROSE PLANTS (JUNE 15, 1946, DRY WEIGHT BASIS)

Length of Shoot	Portion of Shoot	Total N	Protein N	Non-protein N	Free Reducing Substances	Total Sugar	Hemi-reserve Carbohydrates
1 inch	Top third	1.71	0.55	1.16	2.29	1.58	26.80
1 inch	Middle third	1.48	0.73	0.75	2.14	1.58	28.95
1 inch	Lower third	1.89	0.89	1.00	1.98	1.50	26.00
2 inches	Top third	1.66	0.93	0.73	2.54	2.20	27.55
2 inches	Middle third	1.80	1.30	0.50	2.18	0.34	27.60
2 inches	Lower third	2.04	0.83	1.21	2.14	1.24	26.35
3 inches	Top third	1.73	1.06	0.67	2.74	2.94	28.85
3 inches	Middle third	1.67	0.83	0.84	2.47	2.96	29.80
3 inches	Lower third	1.82	0.80	1.02	2.50	2.86	28.75
4 inches	Top third	1.83	0.87	0.96	2.63	2.70	25.50
4 inches	Middle third	1.70	0.86	0.84	2.15	2.76	26.65
4 inches	Lower third	1.84	0.68	1.16	2.57	2.70	29.40
5 inches	Top third	1.71	0.93	0.78	2.14	2.36	——
5 inches	Middle third	1.76	0.80	0.96	2.35	1.02	——
5 inches	Lower third	1.73	0.86	0.87	2.19	1.70	——
6 inches	Top third	1.68	0.91	0.77	2.16	1.44	——
6 inches	Middle third	1.89	0.86	1.03	1.93	1.24	——
6 inches	Lower third	1.95	0.80	1.15	2.34	2.16	——
Longer	Top inch	1.79	1.02	0.77	3.11	2.44	——
Longer	Second inch	1.62	0.98	0.64	2.55	2.46	——
Longer	Third inch	1.64	0.90	0.74	2.60	2.64	——
Longer	Fourth inch	1.81	0.91	0.90	1.92	2.42	——
Longer	Fifth inch	1.82	0.96	0.86	2.42	2.52	——
Longer	Sixth inch	1.79	0.89	0.90	2.31	2.32	——
Longer	Seventh inch	1.66	0.74	0.92	1.73	0.52	——

TABLE VIII—PERCENTAGE COMPOSITION — DRY WEIGHT BASIS BETTER TIMES ROSE SHOOTS CUT OCTOBER 15, 1946

Treatment	Condition	Inches From Top	Total N	Protein N	Non-Protein N	Free Reducing Substances	Total Sugar	Hemi-reserve Carbohydrates
Check	Buds opening	0-2	1.36	1.01	0.35	10.34	8.98	13.35
		2-4	1.38	0.84	0.54	5.00	3.96	14.15
		4-6	1.77	1.02	0.75	3.00	1.88	13.15
	Buds showing color	0-2	1.57	1.18	0.39	12.00	10.46	13.42
		2-4	1.91	1.44	0.47	6.94	5.44	12.92
		4-6	1.79	1.14	0.65	3.42	2.46	12.20
	Small buds	0-2	2.63	2.36	0.27	4.76	2.94	Lost
		2-4	2.15	1.58	0.57	13.60	3.56	9.47
		4-6	1.77	1.23	0.54	14.00	13.16	8.77
	1-inch shoot	0-1	3.16	2.66	0.50	1.48	0.46	12.35
	2-inch shoot	0-1	3.68	3.47	0.21	1.86	0.56	10.72
		1-2	2.91	2.19	0.72	3.08	1.68	12.05
	3-inch shoot	0-1	3.19	2.56	0.63	2.56	—	15.50
		1-2	3.30	2.37	0.93	2.40	0.36	13.85
		2-3	3.01	2.39	0.62	4.52	1.68	14.10
Shaded	Buds opening	0-2	1.45	0.94	0.51	8.26	4.76	12.75
		2-4	1.67	0.90	0.77	4.00	1.16	13.65
		4-6	2.22	1.06	1.16	2.06	—	14.30
	Buds showing color	0-2	1.57	1.19	0.38	9.30	8.00	9.42
		2-4	1.65	1.10	0.55	7.30	6.76	13.12
		4-6	1.90	1.07	0.83	3.00	2.20	12.95
	Small buds	0-2	2.31	2.26	0.05	5.61	4.20	11.15
		2-4	1.91	1.58	0.33	15.00	13.36	9.67
		4-6	1.75	1.26	0.49	12.60	13.00	10.65
	1-inch shoot	0-1	3.14	2.64	0.50	1.08	0.32	14.90
	2-inch shoot	0-1	3.62	3.16	0.46	0.84	0.08	13.85
		1-2	2.74	2.01	0.73	2.44	1.72	15.10
	3-inch shoot	0-1	2.85	1.94	0.91	3.96	3.16	13.45
		1-2	3.29	2.44	0.85	2.42	1.56	14.75
		2-3	3.18	2.54	0.64	4.22	7.04	13.20
4-leaf	Buds opening	0-2	1.44	1.13	0.31	8.54	6.60	13.90
		2-4	1.34	1.05	0.29	1.52	--	14.20
		4-6	1.67	1.00	0.67	2.66	1.36	13.75
	Buds showing color	0-2	1.58	1.28	0.30	9.92	6.08	13.22
		2-4	1.55	1.14	0.41	8.52	2.04	10.62
		4-6	1.60	0.99	0.61	2.50	0.52	11.42
	Small buds	0-2	2.32	2.12	0.20	4.25	3.96	11.12
		2-4	1.66	1.42	0.24	11.05	10.20	10.57
		4-6	1.41	1.19	0.22	8.25	7.88	13.05
	1-inch shoot	0-1	3.02	2.45	0.57	1.24	0.42	10.15
	2-inch shoot	0-1	3.45	3.22	0.23	1.33	0.46	8.95
		1-2	2.57	2.03	0.54	2.40	2.10	10.57
	3-inch shoot	0-1	3.28	2.78	0.50	3.13	2.06	9.47
		1-2	2.95	2.44	0.51	2.30	2.22	9.37
		2-3	2.74	2.30	0.44	3.27	2.24	9.82
2-leaf	Buds opening	0-2	1.24	1.00	0.24	7.40	3.36	13.65
		2-4	1.40	1.00	0.40	2.90	1.80	10.50
		4-6	1.42	1.00	0.42	2.43	1.48	16.00
	Buds showing color	0-2	1.52	1.24	0.28	9.33	8.60	13.10
		2-4	1.55	1.13	0.42	3.83	3.96	13.60
		4-6	1.46	0.91	0.55	2.10	2.20	14.20
	Small buds	0-2	2.50	2.07	0.43	4.16	3.52	10.97
		2-4	1.92	1.48	0.44	10.74	10.12	10.22
		4-6	1.56	1.20	0.36	7.24	7.04	11.50
	1-inch shoot	0-1	3.08	2.48	0.60	1.12	0.20	8.42
	2-inch shoot	0-1	3.40	3.12	0.28	1.38	0.30	9.65
		1-2	2.48	1.86	0.62	2.48	2.04	13.67
	3-inch shoot	0-1	2.98	2.50	0.48	1.48	—	13.80
		1-2	3.05	2.57	0.48	1.96	—	14.05
		2-3	3.14	2.58	0.56	3.42	0.92	13.05

differences in magnitude were not great (Fig. 4). Much greater differences had been shown between other similar shoots at various times during the year. The significant fact is that both newly blind and newly flowering shoots had similar concentration gradients. Mature blind and flowering shoots had markedly different types of gradients. The divergence in chemical composition must therefore

TABLE IX—PERCENTAGE COMPOSITION — DRY WEIGHT BASIS ROSE SAMPLES TAKEN FEBRUARY 15, 1947

Treatment	Condition	Inches From Top	Total N	Protein N	Non-Protein N	Free Reducing Substances	Total Sugar	Hemi-reserve Carbohydrates
Check	Small buds	0-2	2.36	2.02	0.34	9.10	8.48	12.20
		2-4	1.86	1.54	0.32	20.41	22.04	11.05
		4-6	1.39	1.25	0.14	15.30	18.12	12.25
	1-inch shoot	0-1	2.98	2.68	0.30	2.32	2.36	11 00
	2-inch shoot	0-1	3.33	3.10	0.23	2.14	3.50	11.45
		1-2	2.66	2.17	0.49	5.74	5.32	12.40
	3-inch shoot	0-1	3.48	3.05	0.43	2.08	3.74	12.75
		1-2	2.92	2.35	0.57	6 98	6.34	10.65
		2-3	2.33	1.64	0.69	10.90	9.92	11.25
Shaded	Small buds	0-2	2.59	2.22	0.37	14.02	12.92	15.30
		2-4	1.95	1.45	0.50	28.60	27.88	15.50
		4-6	1.46	1.14	0.32	23.68	22.28	15 95
	1-inch shoot	0-1	3.11	2 48	0 63	2 84	2 86	13.65
	2-inch shoot	0-1	3.57	3.05	0.52	2.38	2.40	11.80
		1-2	2.47	1.88	0.59	6.10	6 72	11.30
	3-inch shoot	0-1	3.64	3.32	0.32	2.18	2.02	10.55
		1-2	2.94	2.35	0.59	5.74	5.62	12.35
		2-3	2.21	1.66	0.55	10.54	10.12	8.80
4-leaf	Small buds	0-2	2.24	1.25	0.99	10.60	10.02	10.27
		2-4	1.54	0.89	0.65	14.67	17 56	10.90
		4-6	1.16	1.11	0 05	13.32	12 94	11.75
	1-inch shoot	0-1	2.88	2.57	0 31	4.34	4.32	9 55
	2-inch shoot	0-1	3.37	3 13	0.24	3.28	3.36	17.25
		1-2	2.33	1.90	0.43	10.16	10.02	16 10
	3-inch shoot	0-1	3.19	2.91	0.28	3.56	3.50	16 75
		1-2	2.50	2.16	0.34	8.10	7.80	17.05
		2-3	1.81	1.54	0.27	11.12	10.34	17.40
2-leaf	Small buds	0-2	2.08	1.82	0.26	10.72	9 78	14.90
		2-4	1.27	1.18	0.09	12 90	12.58	11.80
		4-6	1 11	0.98	0.13	5.26	5.34	16 20
	1-inch shoot	0-1	2.98	2.52	0 46	2.84	2 72	17.05
	2-inch shoot	0-1	3.33	2.92	0.41	2.54	1.98	15 00
		1-2	2 22	1.82	0 40	7.82	7.66	12.55
	3-inch shoot	0-1	3.59	3.15	0.44	2.54	2.14	18.55
		1-2	2.63	2.11	0.52	8.26	8 04	16.45
		2-3	1.89	1.38	0.51	9.22	9.08	15.85

have taken place after, not before, the shoots became either definitely blind or definitely flowering.

It is interesting to note that shading had no effect on the incidence of blindness but did have a greater effect than defoliation in increasing carbohydrate concentrations in the stems, yet any amount of defoliation increased the incidence of blindness. The only treatment effective in increasing blindness also destroyed apical dominance in the plants. It is known that this destruction of apical dominance is the result of a decreased auxin supply. Only through a hormonal mechanism, therefore, was it possible to increase blindness.

Although it might be thought that blindness actually resulted from a carbohydrate deficiency caused by an increasing number of developing buds without any increase in stored carbohydrates, shoots from defoliated plants often contained more carbohydrates than similar shoots from check plants.

SUMMARY

1. Mature blind shoots, at all times of the year and at least in three varieties of hybrid tea roses, bear less than half the number of leaves borne by mature flowering shoots from the same plants.

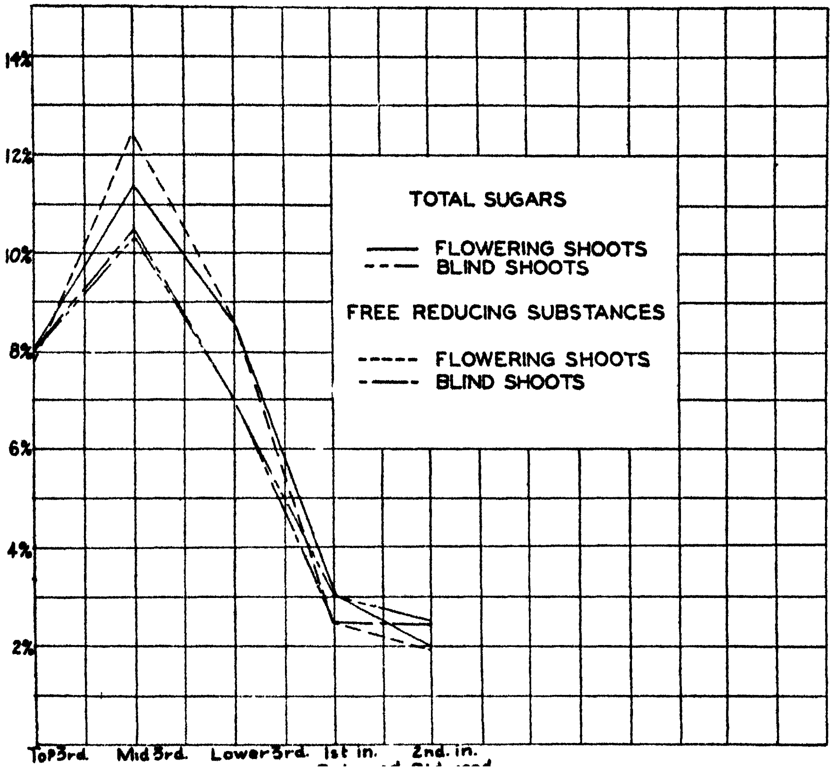

FIG. 4. Chemical composition (free reducing substances and total sugars) of immature shoots just recognizable as blind or flowering, expressed as percentage of dry weight.

2. Shading has no effect on the number of leaves borne on the average blind or flowering shoot.

3. Shading has no effect on the total number of shoots produced by the rose plant.

4. Shading has no effect on the number of blind shoots produced by the rose plant.

5. Defoliation increases the total number of shoots produced by the rose plant.

6. Defoliation increases the number of blind shoots produced by the rose plant.

7. Defoliation increases the percentage of blindness on the rose plant.

8. Certain gradients exist in the stems of the rose plant which are not disturbed by treatments such as shading or defoliation. Shading or defoliation may increase or decrease the magnitude of the various carbohydrate or nitrogen fractions, but the gradients along stems of various types and in various stages of development remain relatively constant.

9. Very small young shoots are relatively low in free reducing substances and total sugars. If any gradients exist, the greatest concentration of these substances is at the base of the shoot.

10. Shoots bearing small buds have the greatest concentration of free reducing substances and total sugars 3 or 4 inches below the bud.

11. Shoots bearing buds large enough to show color have their greatest concentrations of free reducing substances and total sugars in the 2-inch stem segment just beneath the bud. The magnitude of this concentration is usually greater than that found in less developed flowering stems.

12. When the buds open, there is no change in the position of the greatest concentrations of free reducing substances and total sugars in the stem, but the magnitude of the concentrations usually increases.

13. Mature flowering stems are relatively long, with an average of over seven leaves per stem.

14. Mature blind shoots are relatively short, with an average of less than four leaves.

15. Mature blind shoots have no definite composition gradients of free reducing substances or total sugars. The magnitude of these carbohydrate fractions is also small.

16. In no shoots were there consistent gradients of hemi-reserve carbohydrates or of total or protein nitrogen.

17. The chemical composition of shoots just recognizable as blind or flowering were similar in respect to free reducing substances, total sugars, hemi-reserve carbohydrates, total nitrogen, protein and nonprotein nitrogen.

18. Blindness seems to be caused by a hormonal mechanism rather than by a nitrogen-carbohydrate relationship.

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Pollination Requirements of English Holly, Ilex Aquifolium

By A. N. Roberts and C. A. Boller, *Oregon State College, Corvallis, Ore.*

The increasing importance of English holly as an orchard tree in the Northwest has focused attention on the pollination requirements of this crop. The fact that this species is dioecious has been generally known and accepted since 1797 (1), but the production of berries by isolated pistillate trees has long been confused and misunderstood. It was not known whether the berries produced by these occasional isolated pistillate trees were indicative that functioning stamens were present, that berries were produced parthenocarpically, or that pollen had been carried considerable distance by bees. The extent to which this misunderstanding has persisted is shown by the planting in the Pacific Northwest of solid blocks of co-called "bisexual" trees without the presence in the orchard of the staminate pollenizers. Some of these isolated plantings have failed to produce sufficient numbers of berries for commercial cut holly.

Darwin (2), as early as 1886, was of the opinion that *Ilex aquifolium* did not produce perfect flowers. Dallimore (1), although stressing the importance of the male tree in the holly planting for berry production, was of the opinion that occasionally stamens bearing good pollen were found on trees bearing principally pistillate flowers and also at times perfect flowers were found on the male trees. This opinion has not been supported by the experience of workers with this species in this country. Whether this is a matter of difference in types observed or climatic conditions is not known. It was his opinion that the small second crop of blossoms produced in July or August was more likely to be perfect. Dallimore was familiar with the fact that, "it sometimes happens that fruits swell up and mature without containing fertile seeds", so he could not have been confusing this condition as indicative of perfect flowers. As far as we know, Dallimore was the first to record the fact that *Ilex aquifolium* produces berries parthenocarpically.

Locklin (3), in examining hundreds of blossoms of English holly types, found the bloom from staminate trees to have stamens only and the flowers from pistillate trees contained pistils and stamens, but in all cases the stamens contained no pollen. In pollination tests, Locklin found that though none of the blossoms on any of the female trees produced pollen, certain trees would mature some fruits without the introduction of pollen, while others produced practically no berries unless pollen was supplied from the male trees.

Studies of the flower structure and the flowering habits of both pistillate and staminate trees of important commercial clones, as well as many chance seedlings grown in Oregon, failed to reveal either the

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presence of functionally perfect flowers or a combination of pistillate and staminate flowers on any one tree, except in grafted trees where an occasional sucker from the rootstock was of the opposite sex of the cion variety. That a pollination problem existed in commercial orchards was apparent, and studies were therefore undertaken to determine pollination requirements, extent of parthenocarpy, and the influence of pollination and subsequent seed formation on berry size, date of maturity and tendency to drop.

Methods and Procedure

In preliminary studies comparisons were made between ordinary brown paper bags, cloth bags, and screened cages as to their effectiveness in excluding pollen and maintaining normal atmospheric conditions around the flowers. All three were found equally effective since it appears that holly pollen, which is quite heavy, is not windborne to any extent. The abundance of nectar produced by holly flowers is very attractive to bees, and during flowering, which extends over a 2- or 3-week period, holly orchards are a center of bee activity. An isolated pistillate tree on the Experiment Station grounds that had bloomed profusely a number of years without producing berries was caged with a small hive of bees and a bouquet of male flowers for 5 days. The berry crop produced on this tree that season attests to the effectiveness of the bees. Similar female trees in close proximity to male trees have failed to set fertile seed when caged. This would seem to eliminate wind as a factor in the transfer of holly pollen.

Hand-pollination throughout these studies was accomplished by collecting the pollen from selected male trees prior to the time it was to be used and storing it in an ordinary refrigerator. It was possible to maintain high viability for the month or so that it was to be used. Germination tests prior to use were used as a check on the quality of the pollen.

To determine the number of filled carpels or fertile[2] seeds produced in each berry and also those produced parthenocarpically from any given treatment, the berries were sectioned transversely. The fertilized embryo and endosperm develop and swell sufficiently in 3 to 4 weeks following bloom to distinguish them from the "blanks", which result from lack of pollination (Fig. 1). This sectioning could be done with a pocket knife during the early development of the berry, but after the carpel walls started to harden, it was necessary to use hand shears. It was found that if the berries were dried slightly the cutting was considerably easier.

Following these preliminary studies, five holly orchards were selected as representative of the varying conditions that might influence pollination and berry set, such as isolation, number of male trees present, elevation and exposure, soil type, and tree age. Since the principal commercial plantings in the State at the time of these studies were of a fairly true clone known as French-English, four orchards

[2]Fully developed seeds were assumed to be fertile although no germination tests were made.

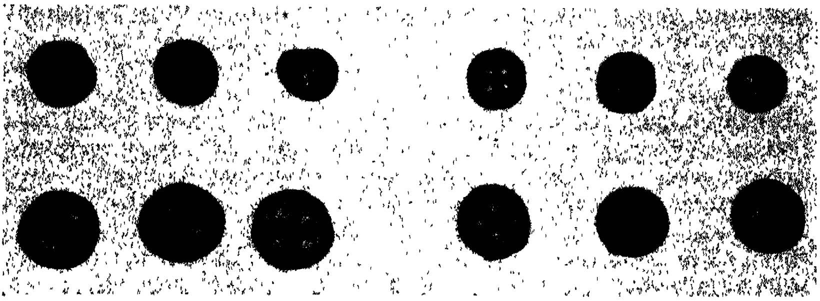

FIG. 1. Parthenocarpic and seeded berries of two varieties of English holly cut transversally to show differences in size and structure 7 weeks after blossoming (upper row — parthenocarpic; lower row — with seed).

(A, B, C, and D) of this variety were selected for study. The other orchard (E) was of a new variety that is being planted extensively in recent years.

The five orchards were located at various points throughout the holly-growing area of the State. Orchard A composed of trees 6 to 8 years of age had several male trees scattered through the 3-acre planting and in close proximity to the pistillate trees studied. The trees in orchard B were 15 to 20 years old and near male trees in all cases. Orchard C was also 15 to 20 years old, but the trees in this crowded orchard were approximately 200 yards from the nearest male tree which was in an adjacent orchard. Orchard D proved to be an ideal one for these studies because of its complete isolation from other holly orchards and the presence of only one small male tree in the entire planting of approximately 17 acres. This 10-year-old orchard was located in the hills at a higher elevation than other orchards studied. The pistillate trees studied in orchard E were of a different variety than those in the other orchards. The orchard was 6 to 8 years old and sufficient numbers of male trees were present for pollination.

During 1946 and 1947 from two to four trees were selected in each of these orchards and several branches bagged prior to opening of the blossoms. When most of the flowers were fully open (May 2 in 1947), certain bags were removed entirely for open-pollination; others were removed and pollen applied with a camel's hair brush and then the bags were replaced. The remaining branches were left covered until the stigmas were no longer receptive. At this time all bags were removed. The number of berries set was recorded in June and the final crop remaining in November was collected and sectioned to determine the degree of pollination and parthenocarpy. Since the data from the two years' tests are quite similar, in order to conserve space, only the 1947 records are used in Table I.

RESULTS

Berry Set:—The percentage of berries set varied considerably from tree to tree in the same orchard and from one branch to another on an

individual tree. However, the results obtained do indicate the pollination situation in the orchard.

The effectiveness of the staminate pollenizers in orchard A is shown in the fairly high sets from open-pollination, which are even better than those hand-pollinated. The apparent erratic results in the open-pollinated flowers in orchard B, where ample male trees were also present, were probably due to the use of a heavy application of nitrogen fertilizer in 1947. In some orchards such procedure has resulted in throwing the trees out of berry production almost completely. Orchard C in both years showed the lack of pollenizers for the trees studied, although the distant male tree was having some effect. The number of berries set was considerably improved by hand-pollination. The pollination resulting from the single male tree in orchard D is discussed in detail later. The four trees used in these tests were at the opposite end of the orchard from this pollenizer, accounting for the poor sets of berries from open-pollination. The two trees in orchard E were adjacent to one of the male trees, hence the good set of berries with open-pollination.

TABLE I—Berry Production in English Holly (*Ilex Aquifolium*) Following Hand-Pollination, Open-Pollination and Without Pollination — Parthenocarpic (1947)

Orchard	No. of Trees	Treatment	Number Flowers	Per Cent Set (May 22)	Per Cent Set (Nov. 5)	(November) Per Cent of Berries With				
						0-seeds (Parthenocarpic)	1 Seed	2 Seeds	3 Seeds	4 Seeds
A	2	Without pollination	802	41	2	100	0	0	0	0
		Hand-pollination	389	67	21	13	48	33	5	1
		Open-pollination	765	87	62	0	15	40	27	18
B	4	Without pollination	845	—	2	100	0	0	0	0
		Hand-pollination	537	—	38	11	35	25	20	9
		Open-pollination	730	—	56	2	26	34	27	11
C	4	Without pollination	482	58	21	100	0	0	0	0
		Hand-pollination	164	98	88	5	14	32	31	18
		Open-pollination	472	74	45	72	22	3	2	1
D	4	Without pollination	1,406	20	9	100	0	0	0	0
		Hand-pollination	238	88	79	11	31	32	21	5
		Open-pollination	1,059	41	21	38	50	10	2	0
E	2	Without pollination	321	40	2	100	0	0	0	0
		Open-pollination	117	93	59	1	28	28	33	10

Parthenocarpic Berry Set:—It is quite apparent (Table I) that some trees and even branches set greater numbers of berries without pollination than do others of the same variety. The variety in orchard E has for several years set very few berries parthenocarpically. Certain of the trees in orchard C have set from 50 to 80 per cent of their flowers without pollination both years they have been observed. Whether these trees vary from the variety type in that characteristic or are a result of individual tree nutrition is not known. Such trees would have value for solitary ornamental plantings if this character is constant. No doubt there are a number of factors such as soil moisture, tree age and nutrition, as well as hormone effects, that determine the numbers of these seedless berries that are produced.

The decrease in the percentage of parthenocarpic berries from the early to the late sampling (Table III) shows the tendency of these berries to drop. This tendency is greatest where there is a heavy set of berries with seed. A berry containing fertile seed will seldom drop. Young trees that are vigorously growing do not ordinarily set many berries without pollination. Setting of seedless fruits on *Ilex aquifolium* with naphthaleneacetic acid sprays is no doubt influenced by this inherent tendency to set fruits parthenocarpically. Following the methods of Gardner and Marth (4) with *I. opaca*, the writers have been able to increase the set of parthenocarpic fruits on trees of *I. aquifolium* with sprays of naphthaleneacetic acid. However, these sprays reduce the drop of parthenocarpic fruits only for a few weeks. Whether repeated spraying would prolong this period was not investigated, since this was not considered a practical means of controlling berry set.

Gardner and Marth used pollen from other plants on *Ilex opaca* pistils without increasing the set of seedless fruits. Attempts by the writers at using *I. latifolia* pollen in certain of these pollination tests with *I. aquifolium* produced interesting results and should be investigated further. Although, not effective in setting fertile seed, the *latifolia* pollen in two instances did materially increase the set of seedless fruits. The tests were not extensive enough to be conclusive, but are interesting from the standpoint of possible effects of pollen from related species.

Effect of Pollination on Berry Color and Size:—The so-called French-English variety of holly was used in most of these tests because of its commercial importance. The late-ripening of its berries is the principal objection against further planting of this variety. Too often the berries are only reddish-brown at cutting time, which starts the last week in November or the first week of December.

It was observed in all orchards where pollination tests were conducted that the berries produced without pollination were much behind the ones with seed in red color development. In most instances, the differences were quite striking. Further examination showed a general tendency for the degree of coloring to be in proportion to the number of fertile seeds in the berry. Samples were taken in each of two years from orchard D and separated into four color groups — green, reddish-brown, red and bright red — and later sectioned to determine the number of fertile seed present. The amount of red color developed was in direct proportion to the number of fertile seeds present (Table II). The samples in 1946 were taken on October 10 and in 1947 on November 6 with the same results. From these and other random samples taken in other orchards, it appears that this color difference persists in varying degree at least through the normal cutting season.

This color difference has been observed in orchards where color development has been a problem and where few if any pollenizer trees were present. In these orchards, the occasional male tree was conspicuous because of the brighter red berries on the berry-bearing trees in its near vicinity. Although the presence of fertile seed is but one

TABLE II—THE EFFECTS OF FERTILE SEED DEVELOPMENT ON THE FORMATION OF RED COLOR IN MATURING HOLLY BERRIES, *Ilex Aquifolium* (OCTOBER 10, 1946)

Color of Berries in Sample	Per Cent of Berries With					Average Number Seeds Per Berry
	0-Seeds (Parthenocarpic)	1 Seed	2 Seeds	3 Seeds	4 Seeds	
Green	40	55	5	0	0	0.6
Reddish-brown	10	46	27	15	2	1.5
Red	5	10	29	37	19	2.5
Bright red*	0	3	19	39	39	3.1

*Sample taken from trees in the close vicinity of the only staminate tree in the orchard.

of the factors involved in color development, it may be the determining one in the case of some varieties that are on the borderline as to satisfactory maturity dates. Some varieties set so few parthenocarpic berries as to not be influenced by this factor. Other varieties are by nature so late in ripening that they are of no commercial value whether pollenized or not.

The difference in size of holly berries containing fertile seed and those developed parthenocarpically is quite obvious (Fig. 1). While no measurements or weights have been taken, they would undoubtedly show considerable difference in favor of the fruits with the fully developed seeds. A further advantage of these seeded fruits over those dveloped without pollination is their greater resistance to withering after the holly is cut. This has been apparent throughout the handling and storage studies made during the course of the investigation.

EFFECTIVENESS OF A SINGLE POLLENIZER

Some information as to the number of pollenizer trees required to provide adequate pollenization in a holly orchard was obtained from the studies made in orchard D. As previously stated this orchard is composed of approximately 17 acres of 10-year-old pistillate trees with only one small staminate tree in an outside row of the block. This small male tree was a replant for one of the pistillate trees destroyed by cultivation when the orchard was first planted.

To determine the effectiveness of this male tree in supplying pollen for the surrounding female trees, a row of trees extending across the orchard from this pollenizer was selected for study. There were 34 trees in the row planted, 25 feet apart, with the farthest tree being 950 feet from the pollenizer (100 feet occupid by an orchard road and fruit trees). During both 1946 and 1947, berry samples of 25 to 150 berries were taken from each of these trees for sectioning to determine the degree of pollination as indicated by the percentages of fertilized and parthenocarpic berries produced (Table III). The berry samples were taken on June 10 and November 21 in 1946, and on May 22, July 9, and November 6 in 1947. Based on the percentage of parthenocarpic berries in the sample, the earlier samples are a better indication of the degree of pollination occurring in the tree, since there is considerable drop of the parthenocarpic fruits through the season. The late sampling gives some indication of the extent of this drop. It ap-

TABLE III—EFFECTIVENESS OF A SINGLE STAMINATE TREE IN AN ENGLISH HOLLY ORCHARD (ORCHARD D — 1946–1947)

Tree No.	Distance From Male Tree (Feet)	May—Per Cent of Berries With:						November—Per Cent of Berries With:									
		0 Seed (Parthenocarpic)		1 Seed	2 Seeds	3 Seeds	4 Seeds	0 Seed (Parthenocarpic)		1 Seed		2 Seeds		3 Seeds		4 Seeds	
		1946	1947	1947				1946	1947	1946	1947	1946	1947	1946	1947	1946	1947
1	25	0	—	—	—	—	—	0	—	7	—	18	—	33	—	42	—
2	50	0	—	—	—	—	—	0	0	6	8	18	19	38	27	38	46
3	75	8	24	12	12	8	44	0	4	5	12	16	20	29	24	50	40
4	100	20	14	16	16	16	48	1	4	22	12	34	24	22	24	21	36
5	125	24	24	12	24	16	24	0	0	33	11	27	36	22	25	18	28
6	150	8	4	36	8	32	20	0	0	33	4	29	20	22	56	16	20
7	175	40	8	16	8	36	32	2	4	54	8	21	24	15	24	8	40
8	200	44	20	20	8	28	24	7	0	52	4	22	20	11	32	8	44
9	225	36	8	12	44	20	16	19	0	57	31	15	27	5	34	4	8
10	(Different variety)			—	—	—	—	—	—	—	—	—	—	—	—	—	—
11	275	44	36	36	16	12	0	17	0	51	32	17	24	10	20	5	24
12	300	32	8	28	28	24	12	9	0	45	53	24	17	14	20	8	10
13	325	68	20	28	32	20	0	14	0	40	28	24	32	12	20	10	20
14	350	60	32	40	20	8	0	5	0	61	48	17	20	8	24	9	8
15	375	72	36	32	12	20	0	26	4	41	56	17	28	8	8	8	0
16	400	64	24	36	32	4	4	21	11	48	50	16	14	12	14	3	11
17	425	20	36	24	20	16	4	30	4	44	46	18	31	5	15	3	4
18	450	48	52	20	4	12	12	13	10	49	49	23	21	12	3	3	17
19	475	76	44	40	8	0	8	53	4	34	44	11	28	2	16	0	8
	(100 foot break in orchard)					—	—	—	—	—	—	—	—	—	—	—	—
20	575	60	64	28	8	0	0	28	42	40	46	21	4	8	8	3	0
21	600	60	60	40	0	0	0	42	22	44	36	10	25	3	14	1	3
22	625	96	60	24	8	4	4	37	7	57	42	5	28	1	14	0	7
23	650	80	60	32	8	0	0	47	31	40	34	10	23	2	4	1	8
24	675	84	76	24	0	0	0	29	15	41	49	21	27	5	9	4	0
25	700	60	76	24	0	0	0	35	17	50	63	10	10	4	10	1	0
26	725	60	76	24	0	0	0	25	31	43	49	18	17	9	3	5	0
27	750	88	76	16	4	4	0	37	19	50	54	9	23	1	4	3	0
28	775	72	96	0	4	0	0	44	30	43	43	9	10	3	13	1	4
29	800	88	88	8	4	0	0	47	40	41	48	6	8	3	4	3	0
30	825	76	80	20	0	0	0	11	34	61	50	19	12	6	4	3	0
31	850	64	80	20	0	0	0	16	45	46	45	15	7	11	0	12	3
32	875	96	96	4	0	0	0	46	45	27	52	11	3	9	0	7	0
33	900	50	92	8	0	0	0	27	58	49	36	13	6	7	0	4	0
34	925	78	68	24	8	0	0	66	19	24	54	6	19	3	4	1	4

pears that the greatest drop of these "blanks" occurs during the earlier part of the season.

The early samples taken in 1946 were not separated on the basis of the number of fertile seeds found as was done throughout the 1947 study. However, the percentages of parthenocarpic and seeded fruits found in this early sampling (taken approximately 1 month after bloom) show the effective range of the male tree (Fig. 2). The percentage of berries with seed drops off rather sharply beyond 100 feet. It would appear from this that under conditions existing in this orchard approximately one staminate tree for each 65 pistillate trees would be sufficient. Probably 1 in 50 would be necessary in years of poor pollination weather, but the possibility of excessive pollination should not be overlooked. It has been observed that trees of some varieties, and in particular the French-English used in these tests, if growing in close proximity to the pollenizer, are inclined some years to set excessive numbers of berries. This may result in loss of color in the foliage and even leaf drop in the vicinity of the berries if the nutrition of the tree is not in proper balance.

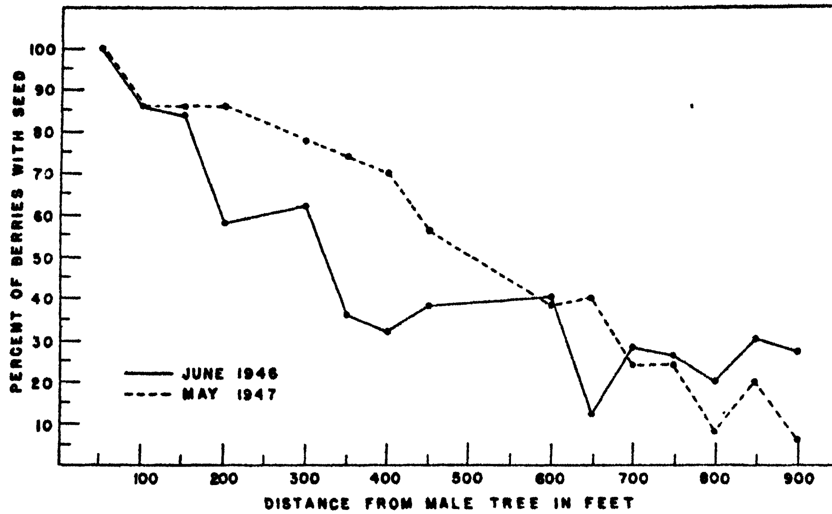

FIG. 2. Degree of pollination occurring in an English holly orchard as the distance increases from the only male tree. Points in the graph represent average of samples from two adjacent trees (Planting distance 25 feet).

SUMMARY AND CONCLUSIONS

Pollination studies at the Oregon Agricultural Experiment Station from 1944 to 1947 with English holly, *Ilex aquifolium,* have shown conclusively the necessity of having sufficient numbers of male trees in the holly orchard to provide adequate pollination and berry set. However, the number of pollenizers required is small when compared with other tree crops. Limited observations indicate that one staminate tree for each 50 pistillate or berry-bearing trees will be sufficient to supply the necessary pollen in normal years. Increasing the proportion of staminate to pistillate trees beyond this number *may* result in too heavy a set of berries in some years and a loss in foliage or foliage color. Staminate trees to be used as pollenizers should be selected on the basis of their foliage quality and at the same time their capacity to produce large amounts of viable pollen at the time the pistillate trees are in bloom.

The tendency of certain varieties of holly to set more berries than others in the absence of staminate trees is due to their ability to produce parthenocarpic fruits. However, of the varieties studied, none produce sufficient numbers of these berries for commercial purposes. It seems probable that the popular misunderstanding of a "bi-sexual" condition (both staminate and pistillate flowers on the same tree or possibly perfect flowers) in English holly has been brought about by the fact that certain varieties do produce considerable numbers of these parthenocarpic berries.

In these studies a comparison of the fertilized berries and the sterile fruits (parthenocarpic) produced by a given variety shows that the

seeded berries are considerably larger, earlier to mature, less subject to pre-mature dropping and more resistant to withering after cutting. Correlations have been made between early berry maturity (color development) and complete berry fertilization following adequate pollination.

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Cytogenetic Studies on Rosa Rubiginosa and Its Hybrids[1]

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THE peculiar meiosis of the Caninae roses was worked out in detail and reported by Täckholm (8). In this particular group are found tetraploid 2n = 28, pentaploid 2n = 35 and hexaploid 2n = 42 forms but in all forms Täckholm found exactly seven pairs at meiosis, the remaining chromosomes behaving as univalents in the reduction division. In the first meiotic division the seven bivalents are arranged in a normal fashion on the equatorial plate with the univalents scattered at random over the spindle. According to Täckholm the bivalents separate normally at anaphase I and proceed to the poles, while the univalents remain behind on the spindle. Later the univalents divide and sister halves are distributed regularly to the two poles. Täckholm reported, however, that all chromosomes were included in the restitution nuclei. At second anaphase the seven chromosomes from the original bivalents divide and the sister halves are distributed to opposite poles. The univalents having divided previously at the first anaphase do not divide again and are left behind in the cytoplasm to form supernumerary microspores. Those microspores receiving exactly seven chromatids from the original bivalents are assumed to be the only functional ones, the others becoming abortive.

The reduction division in the macrospore mother cells is quite different. The bivalents behave as in the divisions of the microspore mother cell; but at anaphase I the univalents do not divide but are all oriented on the micropylar side of the equatorial plate and are included in the micropylar nucleus at the end of the first division. The egg cell finally formed is a derivative of this micropylar nucleus and contains seven less than the somatic number of chromosomes. Thus, if self pollination occurred the resulting progeny would contain the original somatic chromosome number of parent.

To explain this peculiar meiosis in the Caninae roses Hurst (4) advanced a genome theory in which he postulated the existence in the genus Rosa of five differential diploid septets of chromosomes, which he designated as A, B, C, D, E. These septets are supposed to segregate essentially as complete units and the genome makeup of a species may supposedly be determined by a study of the morphological characters which are more or less specific for the various septets. It is further supposed that pairing at meiosis occurs between similar septets. According to Hurst the Caninae roses have resulted from hybridization between species having only one septet in common, resulting in well differentiated species having only seven pairs of homologous chromosomes.

[1]Submitted to the Graduate School of the A. & M. College of Texas in partial fulfillment of the requirements for the degree of doctor of philosophy.

Grateful acknowledgment is made to Dr. S. H. Yarnell for assistance and counsel during the course of this work.

To explain the origin of polymorphy in the Caninae group Täckholm advances a theory of hybridization and believes that the various forms arose from three original crosses, namely:

$7 \times 21 = 7'' \, 14'$ (*Rosa pomifera*)
$7 \times 28 = 7'' \, 21'$ (*Rosa canina*)
$7 \times 35 = 7'' \, 28'$ (*Rosa Jundzillii*)

While there is no evidence in this or other families to suggest the origin of so many forms from only three crosses, he believes that these three crosses arising in the pre-Tertiary era could give rise to the many types through mutation and further crossing. Aneuploid types would arise but these are not assigned a survival value. To explain the survival of so many types he assumes that reproduction in the Caninae roses is principally apomictic, the species still remaining facultatively sexual. Assuming apomixis, he makes no effort to explain the possible survival value of the peculiar meiosis in the Caninae group. Hurst (4) agrees with Täckholm in assuming an original decaploid species to account for *Rosa Jundzillii* Besser (711 281). He based his theory of five differential diploid septets on this ancestral decaploid.

Gustafsson (3) studied the hybrids *canina-rugosa, rubiginosa-rugosa. canina-rubiginosa* and *rubiginosa-canina*. To explain the meiosis in Caninae roses he advanced the theory of internal autotriploidy, according to which these irregular species are assumed to contain three more or less homologous genomes which in pure forms pair only in two's. Such a theory does not explain the absence of trivalents in meiosis of these species.

All investigators up to the present are in agreement in assuming a hybrid origin for the Caninae roses, but no entirely satisfactory theory has been advanced to adequately explain the peculiar type of meiosis found in the group.

The present study of *Rosa rubiginosa* L. and its hybrids is an attempt to explain the interspecific relationships of roses, as indicated by the chromosome behavior of the available interspecific hybrids, reflected in meiosis of the pollen mother cells. In particular it was hoped that the results might throw some light on the validity of Hurst's genome theory, and if the theory appears inadequate to suggest an alternative theory. The Caninae species *R. rubiginosa* was used because it was well adapted to the locality and bloomed consistently with a good set of hips.

Materials and Methods

Sixteen hybrids of *Rosa rubiginosa* L. are included in the present report. Buds were fixed in Allen's modification of Bouin's B15 solution, imbedded in paraffin, sectioned at 12 microns and stained in crystal violet.

Somatic chromosome counts were made from leaf smears according to the method of Baldwin (1).

Taxonomic Characters of Hybrids:—In most instances the hybrids fall into an intermediate class but in general resemble more closely the seed parent. There is one exception to this rule, that of *Rosa rubigi-*

nosa x *R. Täckholmii,* in which the hybrid more nearly approaches the pollen parent in outward characteristics. However, this hybrid received 28 chromosomes from the pollen parent, whereas in the other hybrids 14 chromosomes was the highest carried in the pollen.

A majority of the hybrids have heavier and more dense armature than either parent and are more vigorous.

Leaves, stipules, sepals and bracts are intermediate. Color, shape and size of hips fall into an intermediate class with the exception of the cross with *Rosa Täckholmii* in which these characters resemble more nearly the pollen parent.

In the hybrids hip and peduncle are more or less glandular or glandular spiny regardless of the parentage.

The only character behaving in a clear cut fashion is adnation of the sepals. There are three types of behavior. In one the sepals shed soon after petal fall, in the intermediate type they are held for a time after petal fall and in the third are persistent to maturity. Deciduous x deciduous gives deciduous, deciduous x persistent gives persistent and deciduous x intermediate results in intermediate.

The absence of clear cut modes of inheritance makes classification difficult, and it is small wonder that species naming has gotten out of hand in the genus Rosa.

Results

Crosses:—All crosses made on *Rosa rubiginosa* are listed in Table I in order according to the septet theory of Hurst.

On the basis of Hurst's formulas as shown in the Table there are no septets used in the crosses that show complete incompatibility. The E septet was not available in the diploid form but is represented in the pollen of the regular tetraploid and irregular hexaploid forms. Since Hurst gives the formula ABBCD for *Rosa rubiginosa* the E septet is the only one that would not supposedly find a mate in the egg of the seed parent. From the Table it is obvious that such a foreign septet had little or no influence on compatibility of the parents.

Cytological Results:—Cytological studies were made on 16 different hybrids. The average number of pairs of chromosomes was determined on a minimum of 10 plates. This number is not considered sufficient for statistical treatment, but should give a fair idea of the pairing behavior. The behavior of the chromosomes at meiosis is presented in Table I.

Discussion

The genus Rosa is a freely interbreeding and very polymorphic group. The taxonomic characters show no clear cut mode of inheritance, and environmental influence is so great that it is difficult to separate the various forms into satisfactory taxonomic groups.

The chaos existing in the taxonomic classification led Hurst in 1925 to propose his septet theory, and all species studied were assigned to the five basic diploid sets or a combination of these sets. He did not imply cross sterility among septets but stated only that any pairing in the species or hybrid would be between similar septets. Assuming the

TABLE I—CROSSING RESULTS AND CHROMOSOME PAIRING IN HYBRIDS OF *Rosa rubiginosa* L. LISTED ACCORDING TO HURST'S SEPTET FORMULA

Cross	Flowers Crossed	Per Cent Set	Hybrid Formula	Chromosome Pairing							
				VIII	VII	VI	V	IV	III	II	I
Rosa rubiginosa L. (ABBCD)	—	—	—	—	—	—	—	—	—	7.0	21.0
×*R. Helenae* (AA)......	—	—	AABCD	—	—	—	—	1.2	—	8.4	13.8
×*R. multiflora Thunb.* (AA)	18	22.0	AABCD	—	—	—	—	—	1.5	7.5	15.5
×*R. multiflora Cathyensis* R. and W. (AA)........	19	21.0	AABCD	—	—	—	—	0.73	—	9.6	12.8
×*R. odorata Sweet.* (AA)...	—	—	AABCD	—	—	—	—	—	1.5	7.5	15.5
×*R. Wichuraiana* Crep. (AA)........	—	—	AABCD	—	—	0.08	—	0 23	0.08	9.2	14.9
×*R. Xanthina* Lindl. (BB)	21	33.3	ABBCD	—	—	—	—	1.0	0.17	9.2	12.2
×*R. rugosa* Thunb. (CC)	18	88.8	ABCCD	—	—	—	—	0.45	—	11.2	10.8
×*R. blanda* Ait. (DD) .. .	35	22.8	ABCDD	0.1	—	0.5	—	1.5	—	8.0	9.4
×*R. damascena trigentipetala* D. (AACC) .. .	—	—	AABCCD	—	—	0 34	—	0.67	—	10.0	18.7
×*R. lucida* alba (AADD)	16	56.3	AABCDD	—	—	—	—	0.5	—	13.0	14.0
×*R. heliophila* Greene (CCDD). . .	—	—	ABCCDD	—	—	—	—	2.0	1.3	8.7	12.7
×*R foetida* bicolor Willm. (CCDD) . .	—	—	ABCCDD	—	—	—	—	1.0	1 0	11.0	13 0
×*R. laxa* Retz. (DDEE)	18	66.6	ABCDDE	—	—	—	—	1.0	—	12.2	13.6
×*R. Canina* L. (AABCD)	23	70 0	AABCD	Breakdown at diakenesis							
×*R. Corisfolia froebeli* Christ. (ACDEE) .	—	—	ABCDE	—	—	—	—	—	0.6	6.4	20.4
×*R Tackholmii* Hurst. (AABBCCDD)? .	15	87.0	AABBCCDD	0.4	—	0 8	0 2	—	1.0	14.4	4.0

above theory to be well founded it might be supposed further that a differential compatibility would be found in crosses between the various septets. Such was not found to be the case.

In explaining the origin of the modern roses Täckholm (8) proposed the theory of descent through hybridization and postulated the existence of a primitive decaploid to explain the origin of *Rosa Jundzillii* Besser with 7II + 28I. Hurst (4) agreed in assuming the existence of the decaploid species and proposed the theory that evolution had occurred from this hypothetical decaploid by successive loss of entire septets.

The writer believes that in assuming the existence of such a decaploid the previously mentioned authors are merely avoiding the issue, because it does not seem logical to start with a higher, more specialized polyploid and move downward to the lower and less specialized forms. Further, unless we assume that the decaploid arose from lower, perhaps diploid forms, there would be no basis for considering it a polyploid; instead, we ought to regard it as a primitive diploid n = 35.

Since the known octoploid roses are arctic species, Hurst believes that to assume the origin of our modern forms through ascent would be contrary to our knowledge of the origin of the arctic flora. It is difficult to find logical reasons for such an assumption. The writer sees no great fallacy in picturing the arctic as a once temperate region maintaining a large number of rose forms. With the advent of a rigorous climate the diploids or lower polyploids would be less likely to survive than the higher polyploids due to their lower possible number of beneficial mutations. The higher polyploids would therefore remain and through hybridization and further mutations give rise to new forms. In addition there seems to be little evidence that polyploid

roses are of primitive origin or that they are especially long lived. Darlington (2) has pointed out that the polyploid, and more truly the apomict, is exploiting a momentary advantage at the expense of its long term adaptability. His basis for such an assumption is that ploidy distinguishes species within a genus more often than genera within a tribe or tribes within a family.

Hurst's reasons why evolution of Rosa could not have occurred by ascent from diploid forms are quite obscure, and he is even less convincing in his reasoning for the descent from a primitive decaploid through successive loss of entire septets.

Regarding the Caninae group of roses it seems equally as difficult to explain the origin of such a specialized group through hybridization between species with only one septet in common. If the Caninae did originate in this manner, it is difficult to understand why none of the species show 14 pairs and seven or 14 univalents. In addition, cytological studies on diploid hybrids indicates that in Rosa the various septets are quite similar.

Another unwarranted assumption regarding the Caninae roses is that they are chiefly apomictic but facultatively sexual. Assuming that the irregular Caninae roses have survived through apomictic seed production, it is most difficult to understand how such a reciprocal meiosis as exists in egg and pollen could survive the rigors of selection with no selective advantage. Rather than assume that the Caninae roses have survived in such manner the writer prefers to think of them as a sexually reproducing group maintaining their individual identities through a preponderance of genetic characters inherited through the egg cell. Further it seems reasonable to assume that within the two pairing genomes there exists a high degree of homozygosity. Self fertilization would result in little if any segregation among the offspring, and crossing would perhaps give rise to a high degree of sterility in egg and pollen.

The present cytological studies of hybrids of *Rosa rubiginosa* reveal complete breakdown of the parental meiotic behavior, with a consequent formation of more than seven bivalents and in addition a frequent occurrence of multivalent configurations. This meiotic behavior indicates the existence of a more complicated mechanism controlling pairing in the species of this group. The frequent occurrence of multivalent configurations in the hybrids is probably due to homology between chromosomes of the different septets within the genus, either as more than two homologous chromosomes or more than two homologous segments. The presence of reciprocal translocations might lead to multivalent associations, but this is merely a possible explanation of how the homology between the different septets originated.

From the foregoing results and discussion it seems quite evident that Hurst's septet theory is totally inadequate to explain the type of pairing found among the chromosomes in Rosa species and hybrids in general, and in the Caninae group in particular. According to Hurst's theory a number of the hybrids have a formula identical with or comparable to that of *Rosa rubiginosa,* but they show breakdown of the meiotic behavior with a serious reduction in fertility. Nor is the ex-

planation of Gustafsson (3), based on internal autotriploidy, a satisfactory explanation because such a condition would lead to the occurrence of trivalents in meiosis of the Caninae species. A more satisfactory explanation than simple chromosome homology must be sought to explain the meiotic behavior in this group of Rosa.

An Allelomorphic Series Controlling Meiosis

In the writer's opinion the most likely explanation of the peculiar meiosis in the Caninae roses is that of control through an allelomorphic series of meiosis-regulating genes. It is assumed that each established species is homozygous for a separate allele of the series and that incompatibility between the chromosomes of the different species is the result of heterozygosity at this locus. Such a theory would explain the presence of only seven pairs of chromosomes in this group of species and would also account for the constancy of each species within the group and the separation of the group from others within the genus. It is assumed that such an allelomorphic series has been built up over a long period of time. The several species could have arisen as homozygous types either through selfing or through hybridization between two heterozygous types. Such species once established would remain relatively constant, and if they did hybridize the hybrids would be completely or highly sterile in nature. Such rare hybrids, if they did produce F_2 plants, would give no viable segregates except types homozygous for the meiosis regulating genes, and these would be almost identical with the original seed parent. Backcrosses occurring by chance would be expected to provide a small population of segregates but these can hardly be considered as significant.

In the writer's opinion the data presented here on the behavior of chromosomes of *Rosa rubiginosa* and in hybrids between it and other species are explained satisfactorily by the hypothesis of an allelomorphic series of meiosis-regulating genes, as outlined above, but not by any hypothesis proposed heretofore.

Summary and Conclusions

Cytogenetic studies are reported on a number of interspecific rose hybrids with *Rosa rubiginosa* as the seed parent.

Crossing results indicate a high degree of compatibility between *Rosa rubiginosa* and other species of the genus.

Taxonomic characters distinguishing the species are dependent for their expression on a large number of genes or are the result of segregation in large allelomorphic series. In addition their expression is so modified by environmental factors that classification is exceedingly difficult.

Cytological studies of pollen mother cells shows a complete breakdown of the meiotic system in the Caninae roses following hybridization. The various theories explaining the peculiar meiosis are discussed and their weaknesses pointed out. Gustafsson's explanation, based on internal autotriploidy, is rejected because it does not exclude the possible frequent occurrence of multivalent configurations in the

established species, which is contrary to fact. Hurst's theory precludes this occurrence of multivalents but involves an unwarranted regimentation of the various genomes in Rosa. Separation of species and groups in Rosa presents a sufficiently complex problem without the further complications involved in segregation of chromosomes into strictly defined septets. Neither theory explains the reciprocal meiotic behavior in pollen and egg. However, it must be admitted that, while Hurst's theory does not explain the pairing behavior in Rosa in general and in the Caninae in particular it is not entirely without merit. The first step toward an understanding of relationships among the various species of the genus should be its division into a small number of interrelated groups. Hurst's septet theory, based on aggregates of taxonomic characters and genetic tests furnishes a starting point toward a better understanding of the species and of their phylogenetic relationships.

In conclusion, an alternate hypothesis is offered to explain the peculiarities of meiosis in the Caninae roses. The hypothesis of genetically controlled pairing is more sound because it precludes multivalent configurations, explains the constancy of the several species within the group, and permits continued sexual reproduction. Finally it is the only hypothesis that explains the reciprocal behavior of pollen and egg.

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The Effect of Mulches and Companion Crops on Soil Aggregation and Porosity and on the Growth of Some Woody Ornamental Plants in the Garden and Nursery

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MULCHES for garden roses and other ornamental plants are useful and attractive. Preliminary tests by the junior author showed the uesfulness of living, as well as ordinary mulches, for roses. The studies reported here concern an additional investigation of mulches for roses and the use of companion crops between rows of nursery stock. Companion crops eliminate the need of cultivation and increase soil aggregation and porosity. Studies of this phase of the project are being continued, and the data given here should be considered in the light of a progress report.

Little investigation has been conducted on soil porosity, size and distribution of soil aggregates under sod, mulches, and cultivation treatments in the nursery. The work reported previously has been conducted principally in orchards and with field crops.

Yoder (7) lists the following factors as influencing the granulation of the soils: (a) flocculation and coagulation; (b) cementing materials; (c) wetting and drying; (d) freezing and thawing; (e) organic matter amendments and biotic activity; and (f) tillage operations. Browning and Milan (1) found that easily decomposible material increases immediate aggregate formation, and that a slowly decomposible organic material increases soil agregation over a long period of time. Chandler and Mason (2) reported that a sod mulch retains the soil moisture, keeping the mean above that for clean cultivation, and maintains a lower temperature.

METHODS

The soil aggregation analysis used in this work was made according to the Yoder (6) direct method. Results were expressed as per cent of aggregation and average size of aggregates. Leamer and Shaw's (4) method of measuring noncapillary porosity was used for porosity analysis. A brass soil sampler described by Coil (3) was used to take soil samples in the rose test. Another method was needed to take more samples, and 6-ounce seamless black metal cans 2¾ inches in diameter by 1⅞ inches deep with a $^{3}/_{32}$-inch hole in the bottom were used. A sampler, to hold the can in the sampling of dry or rocky soil, was made from steel pipe. Organic matter content was determined by use of the "Cenco-Wilde" color scale.

ROSE EXPERIMENTS

This experiment was started in the spring of 1944. Twelve plots were established with 20 inches of prepared soil and a 4-inch drain tile running lengthwise of the bed 20 inches below the soil surface. Thirty rose plants, 10 each of three varieties, were used in each plot,

and spaced 16 by 24 inches apart. Controls and the following covers were used in duplicate plots (a) clean cultivation or check; (b) sphagnum peat moss; (c) fresh ground corncobs; (d) Sweet Alyssum; (e) Portulaca; and (f) Alsike clover. Because of its rank growth, Sweet Alyssum was replaced with Chewing's fescue after the first year. The individual plots were mulched or reseeded each spring with their respective cover materials.

The same cultural treatments were continued throughout the three years. Fertilizer applications were made monthly from the first of May to the first of August. Soil tests were made according to the Spurway method (5), and sufficient chemicals and fertilizers were applied to maintain the pH at 6.5 to 7.0, nitrates at 25 to 50 ppm, phosphorus at 5 to 10 ppm, and potassium at 35 to 50 ppm.

Weekly rainfall was recorded, and the difference between actual rainfall and the equivalent of 1 inch, was added to each plot. Plants were sprayed or dusted when necessary to control insects and diseases.

Results and Discussion of Tests on Roses

Table I shows the total number of flowers cut from the two duplicate plots in 1944, 1945 and 1946.

In 1944, the ground corncob plots gave the highest total number of flowers per plant when the data for the three varieties were com-

TABLE I—Total Flower Production of Roses for 1944, 1945, and 1946 Duplicated Plots are Totaled Together

Treatment	Hinrick Gaede			Poinsettia			Mrs. Wakefield Christie Miller			Grand Totals		
	No. Plants	Total No. Flowers	No. Flowers Per Plant	No. Plants	Total No. Flowers	No. Flowers Per Plant	No. Plants	Total No. Flowers	No. Flowers Per Plant	Total No. Plants	Total No. Flowers	Total No. Flowers Per Plant
1944												
Clean cultivation	19	195	10.3	16	127	7.9	10	87	8.7	45	409	9.1
Portulaca	20	217	10.9	20	139	6.9	16	178	11.1	56	534	9.5
Sweet Alyssum	20	105	5.3	20	56	2.8	13	104	8.0	53	265	5.0
Ground corncobs	20	237	11.8	19	119	6.3	16	195	12.2	55	551	10.0
Alsike clover	20	128	6.4	18	83	4.6	10	95	9.5	48	306	6.4
Peat moss	19	118	6.2	20	113	5.7	16	115	7.2	55	346	6.3
1945												
	Hinrick Gaede			Poinsettia			Golden Sastoga					
Clean cultivation	14	87	6.2	18	165	9.2	20	287	14.4	52	539	10.4
Portulaca	17	155	9.1	17	144	8.5	16	200	12.5	50	499	9.9
Chewing's fescue	7	71	7.1	17	103	6.1	19	212	11.2	43	386	8.9
Ground corncobs	17	175	10.2	19	168	8.8	20	282	14.1	56	625	11.2
Alsike clover	9	63	7.0	13	78	6.0	15	112	7.5	37	253	6.8
Peat moss	7	74	7.6	17	129	7.6	15	149	9.9	39	352	9.0
1946												
	Girona			Lady Ashtown			Crimson King					
Clean cultivation	18	231	12.8	16	397	24.8	20	506	25.3	45	1134	21.0
Portulaca	17	241	14.2	14	277	19.8	20	421	21.1	51	939	18.4
Chewing's Fescue	17	156	9.2	16	185	11.6	17	255	15.0	50	596	11.9
Ground corncobs	16	204	12.8	16	257	16.1	20	638	31.9	52	1099	21.1
Alsike clover	16	144	9.0	15	118	7.9	20	341	17.0	51	603	11.8
Peat moss	19	236	12.4	19	212	11.2	19	458	24.1	57	906	15.9

bined. The Portulaca plots were second, and the check or clean cultivation plots were third.

In 1945, the ground corncob plots gave the highest flower production, the check or clean cultivation plots were second, and the Portulaca plots were third.

In 1946, the ground corncob plots and the clean cultivation plots gave essentially the same flower production, and the Portulaca plots were next in order.

While the figures from Table I indicate that there was little difference between the three best plots, they were better than the other three. However, based on flowers per plant and extent of growth, any significant difference in the three best plots favors the corncob mulched plots, while the Portulaca plots and the clean cultivation plots were about the same.

The corncob plots each had 20 per cent organic matter when treated by the Cenco-Wilde method. The other plots ranged from 12 to 6 per cent. All the plots were mulched during the winter of 1945–46 with corn stover, and the portion that was not easily removed was incorporated into the soil in the spring. This, plus the fact that peat moss was mixed with the soil when it was prepared, accounts for the fact that none of the plots were lacking in organic matter.

The percentage of non-capillary porosity of six of the rose plots is shown in Fig. 1. Only one of the duplicated plots is shown.

The corncob plot had the lowest amount of air space, while the Chewing's fescue and the Alsike clover plots had the highest, with the others intermediate. The moisture content of the soil was not constant in all plots at the time of sampling. The soil remained moist under a corncob mulch, and due to the swelling of soil colloids, may have accounted for the decrease in porosity in these plots.

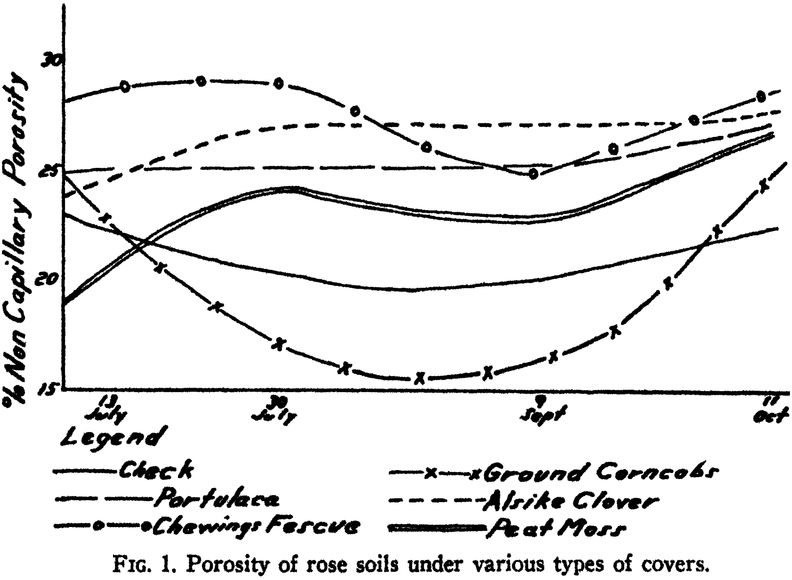

FIG. 1. Porosity of rose soils under various types of covers.

The aggregation analysis for the same plots is shown in Fig. 2. The corncob plot showed the highest percentage of aggregation. The Alsike clover plot was the lowest, with all the other plots intermediate and approximately the same.

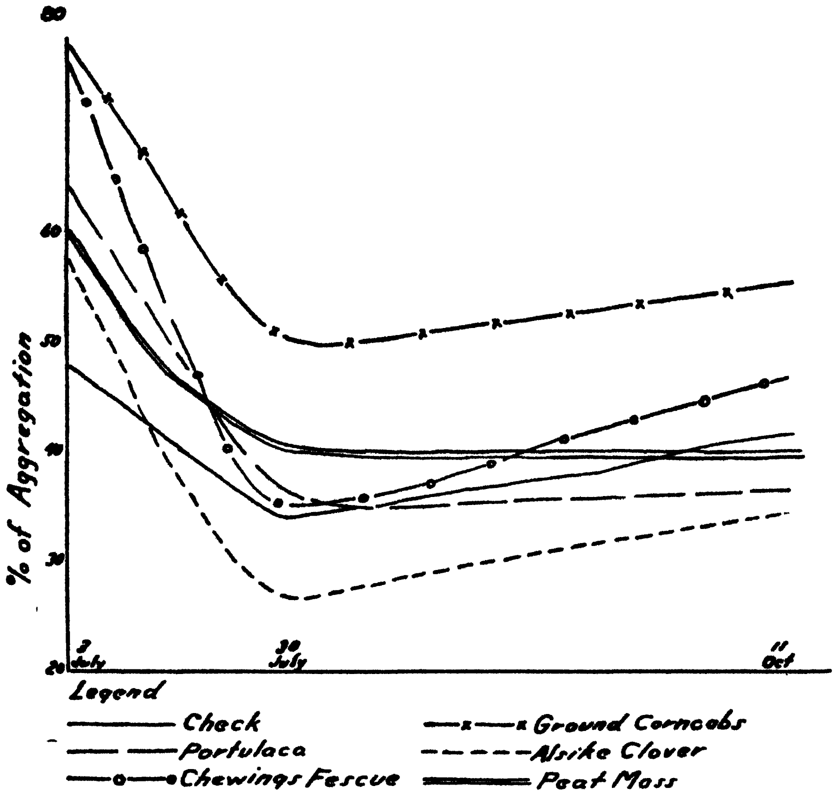

FIG. 2. Aggregation of rose soils under various types of covers.

The corncob plots showed the greatest proportion of aggregates of the larger sizes, while the Portulaca and the Chewing's fescue plots were the lowest in size of aggregates. The size of aggregates showed a tendency to follow the percentage of aggregation. This was definitely the case in the corncob plots, but not so striking in the other plots.

The correlation between soil structure and flower production is not too apparent with all the plots. The Alsike clover plots had the lowest percentage of aggregation and the lowest flower production. Likewise, the two plots having the highest amount of air space were low in flower production.

CORNCOB MULCH EXPERIMENT

To further check the effects of a corncob mulch, sterilized potting soil was placed in 3- and 5-gallon crocks and placed in a greenhouse.

One set, consisting of a 3- and a 5-gallon crock, was left as a check with no mulch applied. Another set had 2 inches of ground fresh corncobs, while a third set contained 2 inches of ground, old, leached corncobs.

RESULTS AND DISCUSSION

Results of porosity samples and aggregation samples taken after 2½ months from the top of the soil are shown in Table II.

TABLE II

Treatment	Per Cent of Non-Capillary Pore Space	Per Cent of Aggregation
Clean cultivation		
3-gallon crock	25.0 22.7	23.7
5-gallon crock	26.1–24.4	27.5
Fresh corncobs		
3-gallon crock	30.5–32.2	32.5
5-gallon crock	30.5–30.5	37.5
Old corncobs		
3-gallon crock	26.1–25.0	29.3
5-gallon crock	23.8–25.0	28.8

The fresh corncob sets showed the highest percentage of noncapillary porosity, while the check and old corncob sets were approximately the same.

The set of crocks with the fresh corncob mulch had the highest percentage of aggregation and also the largest size of particles. The clean cultivation set was lowest in both respects, while the old corncob set was intermediate.

The results show increased aggregation and increased porosity under the fresh corncobs, which is contrary to the results of porosity obtained in the rose plots with the same mulch. The difference may be due to the different soils used and moisture content of the soil at the time of sampling, for the soil samples were taken at the same tension meter reading.

A chemical Shaffer-Hartman analysis was made on fresh and old corncobs, but a negative report was found on reducing and nonreducing sugars. It is apparent, however, that some water-soluble product is leached from fresh ground corncobs to cause an increase in soil aggregation, and is not abundantly found in old corncobs.

PROGRESS REPORT ON TESTS WITH TAXUS

The Taxus plot was set up in the Horticulture Department nursery on a Fox silty clay loam soil, and is not to be correlated with the rose tests. Two-year *Taxus cuspidata* plants were set out in 1945 in 100-foot rows, 36 inches apart, 50 plants in a row. The following companion sod crops were grown between the rows: Alsike clover, Black Medic, Chewing's fescue, and Kentucky Bluegrass. Two rows were kept under clean cultivation.

Porosity and aggregation samples were taken in 1946 with the can samplers 4 inches below the soil surface.

Results and Discussion

The average height and width measurements of a row of plants growing between the same sod crop are shown below:

	Height (Inches)	Width
Chewing's fescue (48 plants)	12.08	7.56
Clean cultivation (49 plants)	16.53	12.36
Bluegrass (44 plants)	12.56	7.31
Alsike clover (46 plants)	13.84	8.41
Black medic (46 plants)	12.30	8.41

The plants under clean cultivation were the largest, having made the most growth during the past season. The plants from the Chewing's fescue strip were the poorest plants in the entire plot.

The Kentucky Bluegrass strips had slightly lower non-capillary porosity, while the other four strips were nearly the same throughout the summer season of 1946.

The results of aggregation are shown in Fig. 3. The Bluegrass strip had the highest percentage of aggregation, while the Chewing's fescue strip had the lowest percentage of aggregation during most of the season, and the poorest plants.

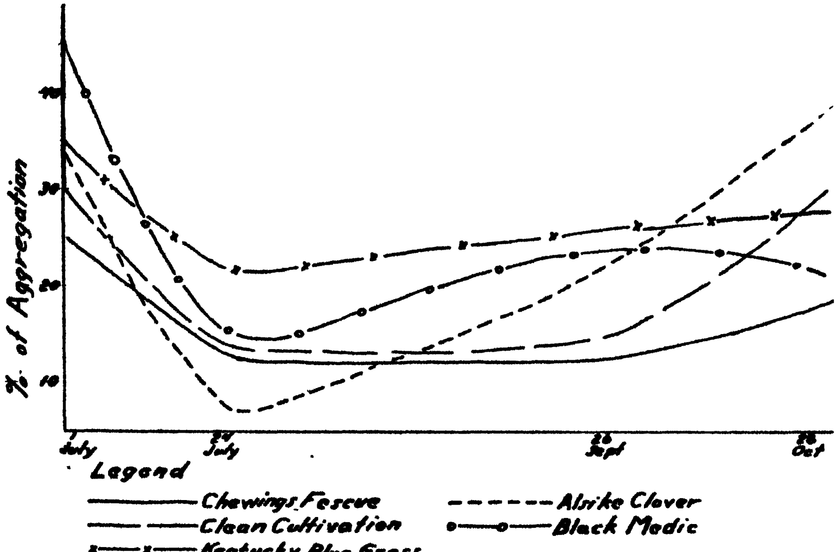

Fig. 3. Effect of various companion sod crops on aggregation of soil in Taxus planting.

The roots of the plants were just beginning to grow under the sod crops, and this may affect the size of the plants in the next few years. While the clean cultivated plants were the largest in the test, it was apparent that on the sod crops the plots having the highest percentage of soil aggregation also had larger plants than those of poor aggregation.

Shade Tree Experiment

An Ohio nursery cooperating with the University seeded half a block of 5-year-old shade trees with Alsike clover in 1945. Prior to 1945, the block was kept under clean cultivation. The soil of this block was a Miami silt loam.

Results and Discussion

The caliper measurements on several types of trees, taken 3 feet above the ground from the two treatments, are as follows:

Tilia cordata, Little Leaf Linden (planted 1942)
- Clean cultivation (63 trees) — 1.68 inches diameter
- Alsike clover (59 trees) — 1.87 inches diameter

Platanus acerifolia, London Plane Tree (planted 1943)
- Clean cultivation (62 trees) — 1.33 inches diameter
- Alsike clover (49 trees) — 1.35 inches diameter

Quercus borealis maxima, Eastern Red Oak (planted 1943)
- Clean cultivation (33 trees) — 0.95 inches diameter
- Alsike clover (29 trees) — 1.22 inches diameter

Approximately 10 London Plane trees of 2 inches in diameter or more were dug from the Alsike clover plot in the winter of 1945–46. Had these trees remained, the average caliper would have been larger in the Alsike clover plot as compared to those under clean cultivation.

The caliper measurements show in the case of the other two groups of trees that their diameter was greater from the Alsike clover plot, and showed less variation in growth than those clean cultivated.

In the Alsike clover plots, the non-capillary porosity remained constant during the summer of 1946. In the clean cultivation plot the non-capillary porosity was higher at the start, but finally dropped below that of the Alsike clover plot.

The percentage of aggregation and size of particles were larger in both cases in the Alsike clover plot than in the clean cultivation plots, and had a slightly higher percentage of organic matter.

There was no apparent difference in the soil nutrients from the cultivated and Alsike clover plots.

In digging trees at the nursery, the diggers preferred trees grown in the Alsike clover plots. During wet weather the soil was less sticky, and in the winter the soil was not frozen as deeply under Alsike clover, making digging easier.

Summary

In the mulched outdoor rose study, ground fresh corncobs were the best, based on flower production and growth, with clean cultivation and Portulaca next. Peat moss plots were average, and Chewing's fescue and Alsike clover the poorest.

No direct correlation could be made on the effects of soil aggregation and flowers per plant. However, the two plots having the highest amount of air space were low in flower production.

In a crock experiment conducted in a greenhouse, it was shown that in the process of decomposition of a ground fresh corncob mulch,

some water-soluble products are leached out, which causes an increase in soil aggregation. These products are not abundantly present in the old corncobs.

In a companion sod crop test on *Taxus cuspidata* plants, the plants under clean cultivation were the largest. Those plants between strips of Chewing's fescue were the poorest, and the plants between Alsike clover, Kentucky Bluegrass and Black Medic were intermediate in size.

Alsike clover in a shade tree block improved the soil aggregation as compared with clean cultivation. The trees were of a larger caliper after two years, and were easier to dig than those under clean cultivation.

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Notes on Growth Habits and Pinching of Hydrangeas[1]

By C. W. Dunham and R. H. Roberts, *University of Wisconsin, Madison, Wis.*

Growth habits of hydrangeas have been observed for the past two seasons at the University of Wisconsin in order to determine how such information can be utilized in commercial culture.[2] One hundred hydrangea plants of variety Kunert and 150 plants of variety Hamburg were started from cuttings taken on January 18 through March 1. Each plant was given a number, and a record was kept of the date and level of the pinches made. Two growth habits of hydrangeas, the characteristic size of leaves at different nodes and the phyllotaxic position of the leaf subtending the new break, were found to influence the success of the cultural practice of pinching.

It has been observed in previous work that when hydrangeas are pinched, the stem diameter of any resulting break is associated with the area of its subtending leaf. It has also been noted that the size of the flower head in the hydrangea is correlated with the diameter of the stem upon which it is borne. The dimensions of leaves subtending buds that were to produce new breaks were recorded May 25 and again on July 20, when the diameter of the breaks was also recorded. Table I shows the relation of the size of the subtending leaf to the diameter of the break produced. The larger the subtending leaf the larger the diameter of the break that arises from its axil.

TABLE I—The Effect of the Size of the Subtending Leaf on the Diameter of the Resulting Break (All Plants Pinched May 25)

Plant No.	Subtending Leaf May 25 (Inches)	Subtending Leaf Aug 20 (Inches)	Break Diameter Aug 20 (Mm)
1	5 × 4	6 × 4¾	5.1
2	5½ × 3	6 × 4	4.1
3	5½ × 4	5½ × 4¾	5.0
4	5 × 4	5½ × 4¾	5.1
5	5 × 3½	5 × 4½	5.0
6	3¼ × 3¾	5½ × 4	5.0
7	5 × 3¼	5½ × 3¼	4.4
8	5 × 3	5¾ × 3¼	4.0
9	5½ × 3¼	5¾ × 3¼	4.0
10	3½ × 2	3½ × 2	3.3
11	3 × 2	3½ × 3	3.3
12	3 × 2	3 × 2	3.0

Correlation of leaf length and break diameter r 0.8356

The diameter of flowering stems in millimeters and the diameter of flower heads in inches of 89 plants were measured at the time of flowering. The stem diameter was taken at the base of the stem at the widest part. The diameter of the flower heads was measured when all flowers were fully expanded. One millimeter of stem diameter was found to be equivalent to approximately 1 inch of blossom diameter, as shown in Table II.

[1]Published with permission of the Director of the Agricultural Experiment Station.

[2]Supported in part by a grant from Holton and Hunkel, Florists, Milwaukee, Wisconsin.

TABLE II—THE RELATION OF STEM DIAMETER TO BLOSSOM DIAMETER

Stem diameter (Mm)	3	4	5	6	7	8	9	10
Average flower diameter (Inches)	3.3	4.3	5.5	7.6	8.5	9.5	10.4	11.5
No. of Plants	7	15	23	12	13	12	5	2

Correlation of stem diameter and blossom diameter r 0.68

How does the habit of growth of hydrangeas affect the size of any given pair of leaves? The normal habit of growth of the hydrangeas is such that whenever a dormant shoot or a new break begins growth, the first pair of leaves produced is small in comparison with the succeeding pairs of leaves. Pinching to small leaves results in breaks with thin stem diameters that produce small flower heads. To obtain vigorous breaks from the first pinch on young hydrangea plants, it is only necessary to pinch at a node so that large leaves subtend the buds from which the break will arise.

How is the phyllotaxy of the hydrangea related to pinching? In making the second pinch in hydrangeas, the phyllotaxic position of the first and third pairs of leaves was found to be of primary importance. The arrangement of the leaves of the hydrangea is such that the first and third pairs produced on the breaks from the first pinch are not in the same plane as the crotch formed on the original stem. The second pair of leaves formed has one leaf of the pair directly in line with the crotch formed by the two branches. It was found that a break produced from a bud directly over a crotch does not have the

FIG. 1. Left, a hydrangea plant where the second pinch was made to the second pair of leaves showing the failure of the two breaks directly over the crotch. Right, a hydrangea plant showing the four breaks produced from the second pinch when none of the breaks are in line with the crotch.

same potential for development as does a break produced from the outside bud opposite it. In many cases the break directly over a crotch soon dies, or in other cases where it does survive, it often results in a blind shoot (Fig. 1).

Thus it is that in making the second pinch in hydrangeas to produce four equal breaks, it is important to pinch to either the first or third nodes where neither of the axillary buds are in line with the crotch formed by the branches from the first pinch. Breaks that develop from the buds in the axils of the third pair of leaves possess a larger stem diameter than breaks from the first node because of the greater size of the subtending leaves at the third node.

Summary

The success of the second pinch on hydrangeas to produce new branches was found to be related to two growth habits. The arrangement of leaves on the branches produced from the first pinch is such that of the first three pairs of leaves produced, only the buds in the axils of the first and third pairs are capable of producing two equally vigorous breaks. One leaf of the second pair of leaves is directly in line with the crotch formed by the two branches of the first pinch, and the bud in its axil in line with the crotch results in a weak shoot. Leaves produced at the third node on hydrangeas are larger than leaves produced at the first node. Breaks produced from the buds in the axils of large leaves possess a greater stem diameter and are capable of producing larger flower heads than are breaks from the axils of smaller leaves.

The Effect of Various Amounts of Potassium on the Production and Growth of Better Times Roses Under Glass[1]

By JOHN R. CULBERT and E. I. WILDE, *The Pennsylvania State College, State College, Penn.*

FLORISTS have different opinions on the level of potassium in soils required for the optimum growth and development of greenhouse roses. This 4-year study was conducted to observe the effect of various amounts of potassium chloride applied to the soil on the number and quality of flowers produced and on the vegetative growth made by greenhouse-grown Better Times roses. This investigation was concerned with relatively small applications of potassium; the effect of larger quantities is the subject of studies to be made later.

The soil used in this study was Hagerstown silty clay obtained from one of the plots lowest in potassium of the Jordan fertility plots. The Jordan fertility plots were established at the Pennsylvania Agricultural Experiment Station in 1881. Between 1881 and 1938 the soil in this plot had received nitrogen and phosphorus twice in each crop rotation but had received no potassium. The soil used contained 93 pounds of total exchangeable K_2O per acre at the time it was secured, an amount which is considered too low for good rose production.

In previous studies (4) with Hagerstown silty clay used without amendments for roses it was found that this soil cracked and shrank enough on partial drying to cause serious root injury and was otherwise unsuited for rose growing in the greenhouse. Therefore, equal parts of soil and river sand were thoroughly mixed together to serve as the medium; the percentage of potassium thus was reduced by half.

Dormant, started eye, budded plants of the variety Better Times were planted in the soil on February 23, 1942. The plots were approximately 15 square feet and accommodated 16 plants. Six different fertilizer treatments were included and these were replicated four times. The plots were randomized on two greenhouse benches.

The plants were pinched twice after planting, and no further pinching was done. They were maintained in continuous production throughout the study. During March, April and May of each year (except the first) the plants were pruned back gradually as the flowers were cut. Surface watering was practiced and good commercial methods were followed in other cultural respects.

No mulching was done during the first year. Because of lack of organic matter and the large proportion of sand, the soil tended to dry out rapidly. A peat mulch applied in the summer of 1943 aided in maintaining more uniform soil moisture, and the mulch was retained continuously throughout the study. Although a few roots grew into the peat, it was found when the plants were dug at the end of the study that the great majority of the roots were in the soil mixture under study.

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The six fertilizer treatments comprised by the study are shown in Table I. The potassium chloride was added in two applications a year, each of one-half of the respective quantities listed, dissolved in water and sprinkled upon the soil surface.

TABLE I—PARTS PER MILLION OF NO_3, P, AND K IN THE SOIL EXTRACT AS AFFECTED BY VARIOUS INCREMENTS OF FERTILIZERS (AVERAGE FOR 4-YEAR PERIOD)

No.	Treatment (Pounds Per 100 Sq Ft)			ppm*		
	KCL	$NaNO_3$	Superphosphate	NO_3	P	K
1	0.000	2.75	1.5	3.0	1.5	3.3
2	0.166	2.75	1.5	3.5	1.3	4.0
3	0.333	2.75	1.5	4.0	1 3	5.0
4	1.000	2.75	1.5	5.0	1.3	9 0
5	2.000	2.75	1.5	4.0	1.5	17.0
6	2.000	5.50	3.0	11 0	3.6	14 0

*Spurway soil test values (ppm on soil extract).

Nitrogen was supplied as sodium nitrate dissolved in water and applied to the soil surface when soil tests and plant growth indicated a need. Phosphorus was supplied as 16 per cent superphosphate. Treatments I, II, III, IV, and V received equal amounts of nitrogen and phosphorus as follows: approximately 2.75 pounds $NaNO_3$ per 100 square feet per year in 11 applications, and 1.5 pounds of superphosphate per 100 square feet per year. Treatment VI consisted of 5.5 pounds of $NaNO_3$ per 100 square feet per year in 11 applications, and 3.0 pounds of superphosphate per 100 square feet per year.

The Spurway system with some modifications was used in making frequent soil tests. The peat mulch was not included in the soil samples.

Records were kept of the number of flowers cut, stem length in inches (including the flower but not so-called hooks), green weight of stems in grams (including the flower but not hooks) and green weight in grams of all other wood removed. This latter item included hooks, fallen leaves, prunings and blind wood removed. Total weight included the green weight in grams of all growth, flowering and vegetative, removed from the plant. These measurements are summarized in Table II. The flowers were separated further into various grades based on stem length. These data appear in Table III. The percentages of flowers in each of the various grades are given in Table IV.

NUTRIENT LEVELS

In Table I are shown the average soil tests for nitrates, phosphorus, and potassium for the 4-year period of the study. The levels of these nutrients are quite low when compared with the generally accepted optimum quantities for roses. Post and Howland (3) suggested an optimum range of 25 to 75 ppm of nitrates for roses and Laurie and Kiplinger (1) suggested 10 to 25 ppm of nitrates, 5 ppm of phosphorus, and 20 to 40 ppm of potassium. All values are ppm on soil extract Spurway system. It was felt that since the amounts of potas-

sium applied to the low potassium soil used in this study were small, the levels of nitrogen and phosphorus also should be low.

Plots which received no potassium during the 4-year period tested approximately 3.0 ppm of readily available potassium at both the beginning and the end of the study. The Hagerstown silty clay used in the study apparently is well supplied with potassium minerals which become available rapidly enough under greenhouse conditions to furnish appreciable quantities of potassium.

The addition of small quantities of potassium, 0.166 and 0.333 pound KCl per 100 square feet, raised the level of available potassium only slightly above that of the soil receiving no potassium.

One pound KCl per 100 square feet per year increased the amount of available potassium to an average of 9.0 ppm and 2 pounds KCl per 100 square feet pear year increased it to an average of 14.0 to 17.0 ppm over the 4-year period.

Tests for nitrates and phosphorus made on soils from plots receiving 2 units of NP (each unit being 2.75 pounds of sodium nitrate and 1.5 pounds of superphosphate per 100 square feet per year) were consistently twice as high as for the other treatments which received only 1 unit of NP. Tests for nitrates and phosphorus made on soils from treatments receiving only 1 unit of NP showed only slight variations between treatments.

As shown in Tables II, III, and IV the plots receiving 2 pounds KCl and 2 units of NP, the maximum quantities of fertilizers applied in this study, produced the most flowers, the longest and heaviest stems and flowers, and the greatest total growth of any of the treatments. It is reasonable to assume that the inferior growth and production of flowers by the plants on the other plots receiving different treatments were due to the lower level of nutrients available to them.

Appearance of Plants

It was interesting to observe during the progress of this study the growth of the plants in the soil receiving no potassium. Although this essential element was constantly at an extremely low level the plants grew in a manner characteristic to the variety Better Times even though their growth and production of flowers was low when compared with that of plants supplied with more usual amounts of potassium. At no time during the growth of the plants were potassium deficiency symptoms observed as described for roses by Laurie and Wagner (2). The flowers were of average size and color, were of good quality, and the foliage was of good color and average size for the variety Better Times. The number of flowers produced was somewhat below good commercial production, and stem length was shorter than for good commercial roses. In view of the fact that this soil would be regarded as a poor one by most rose growers, the production and growth were better than was to have been expected.

High levels of potassium in the soil have frequently been suggested to increase the resistance of rose plants to diseases. Outbreaks of mildew occurred occasionally; however, at no time was any difference

observed in susceptibility or resistance of plants in soils receiving different amounts of potassium. Black spot did not occur during the 4-year study.

Flower Production

As shown by the data in Table II, the plots receiving 2 pounds of KCl and 2 units of NP produced from 3.39 to 4.37 more flowers per plant per year than did any of the other plots. A difference

TABLE II—Means of Number of Flowers, Stem Length, Green Weight of Flower Stems and of All Wood Removed from Plots Under Different Treatments in the Four-Years

	Treatment (Pounds Per 100 Square Feet Per Year)							
KCl	0.00	0.166	0.333	1.00	2.00	2.00	Mean	Required
$NaNO_3$	2.75	2.75	2.75	2.75	2.75	5.50	Per	for Significance
Superphosphate	1.50	1.50	1.50	1.50	1.50	3.00	Year	
	Mean Number of Flowers Per Plant							
1942–43	23.75	24 41	23.75	23.13	22.92	26.08	24.01	5 per cent—
1943–44	20.88	20.55	20.11	20.75	20.55	25.45	21.39	0.58
1944–45	15.81	17.38	17.16	18.50	15.91	21.13	17.65	1 per cent—
1945–46	15.75	16.58	16.73	16.33	15.58	19.80	16.96	0.78
Four-Year mean	19.05	19.73	19.44	19.58	18.75	23.12		
Required for significance	5 per cent—0.71; 1 per cent—0.95							
	*Mean Stem Length (Inches)**							
1942 43	13.77	13.78	13.79	14.20	13.94	13.75	13.87	5 per cent—
1943–44	12.81	13.29	13.50	14.44	14.40	14.42	13.81	0.39
1944 45	10.64	11.47	11.85	13.27	14.28	13.74	12.54	1 per cent—
1945–46	9.75	11.04	11.37	12.23	12.22	13.88	11.75	0.54
Four-Year Mean	11.75	12 40	12.63	13.54	13.71	13.95		
Required for significance	5 per cent—0.48; 1 per cent—0.66							
	Mean Green Weight Stems (Grams)							
1942–43	12.10	12 13	12.37	12.87	12.56	12.32	12.39	5 per cent—
1943–44	13.02	12.78	12.96	13.89	14.45	13.67	13.46	0.43
1944–45	11.16	11.69	12.52	13.57	15.05	14.46	13.08	1 per cent—
1945–46	9.68	11.14	11.44	12.20	12.67	13.13	11.71	0.60
Four-Year Mean	11.49	11.94	12.32	13.13	13.68	13.40		
Required for significance	5 per cent—0 53; 1 per cent—0.73							
	Total Green Weight All Wood Removed (Grams)							
1942–43	331.9	342.1	343.5	348.8	334.8	374.9	346.0	5 per cent—
1943–44	417.4	422.4	414.9	449.5	456.0	535.1	449.2	3.5
1944–45	289.5	318.4	329.1	371.8	359.6	433.6	350.3	1 per cent—
1945–46	304.0	361.7	376.8	387.2	384.8	485.5	383.3	4.9
Four-Year Mean	335.7	361.2	366.1	389.3	383.8	457.3		
Required for significance	5 per cent—4.3; 1 per cent—6.0							

*Mean stem length and mean stem weight include the stem together with its flower.

TABLE III—Mean Flower Production by Grades for 4-Year Period

Treatment	Grades (Inches of Stem Length)							
	Under 8	8-12	12-15	15-18	18-21	21-24	Over 24	Total
I. 0.000 lb KCl 1 NP	820	1,756	1,126	681	293	118	81	4,875
II. 0.166 lb KCl 1 NP	626	1,882	1,263	734	342	130	73	5,050
III. 0.333 lb KCl 1 NP	577	1,712	1,295	802	348	152	86	4,975
IV. 1.000 lb KCl 1 NP	387	1,526	1,483	950	415	161	115	5,037
V. 2.000 lb KCl 1 NP	360	1,360	1,348	989	413	180	111	4,797
VI. 2.000 lb KCl 2 NP	365	1,658	1,660	1,318	617	205	96	5,919

TABLE IV—MEAN PERCENTAGES OF FLOWERS IN THE DIFFERENT GRADES DURING THE 4-YEAR PERIOD

Treatment	Grades (Inches of Stem Length)							
	Under 8	8–12	12–15	15–18	18–21	21–24	Over 24	Total
I. 0.000 lb KCl 1 NP.	17.0	36.0	23.0	14.0	6.0	2.3	1.7	100.0
II. 0.166 lb KCl 1 NP....	12.0	37.0	25.0	15.0	6.7	2.6	1.7	100.0
III. 0.333 lb KCl 1 NP....	11.6	34.4	26.1	16.0	7.1	3.1	1.7	100.0
IV. 1.000 lb KCl 1 NP ...	7.7	30.3	29.4	18.8	8.2	3.2	2.4	100.0
V. 2.000 lb KCl 1 NP.....	7.5	28.3	28.7	20.5	8.6	3.8	2.6	100.0
VI. 2.000 lb KCl 2 NP ...	6.2	28.1	28.1	22.3	10.5	3.5	1.3	100.0

of 0.95 is required for significance at the 1 per cent level. The mean yield of flowers from the plots receiving 2 pounds of KCl and 2 units of NP is, therefore, very significantly greater than that from any other treatment. Since the application of 2 pounds of KCl and 1 unit of NP produced the least number of flowers of any of the treatments it would seem to indicate that the effects of potassium on flower production are dependent to a great extent on an adequate supply of nitrogen and phosphorus. The number of flowers produced with the treatment just mentioned is significantly or very significantly less than that from plots receiving 0.166, 0.333, or 1.0 pound of KCl and 1 unit of NP, or 2.0 pounds of KCl and 2 units of NP per hundred square feet. The mean difference among yields of plots receiving 0.0, 0.166, 0.333, or 1.0 pounds of KCl are not statistically significant.

Production of flowers decreased consistently year after year during the 4 years of the study. The largest decrease during this period was 8.0 flowers per plant in plots receiving no potassium; the smallest decrease was 6.28 flowers per plant in plots receiving 2.0 pounds of KCl and 2 units of NP. It is interesting to note that there was a decrease of 7.44 flowers per plant in the plots receiving 2.0 pounds of KCl and 1 unit of NP; this decrease was greater than that of any of the other plots except those receiving no KCl and 0.166 pound of KCl.

These yearly decreases in production are even larger than shown in Table II since flowers were cut during only a 9-month period in the first year; in all other years flowers were cut in every month of the year. This decrease in production over a 4-year period is a common occurrence in greenhouse rose plants. The levels of nitrogen, phosphorus and potassium used in this study were low when compared to the optimum levels suggested by Laurie and Kiplinger (1) and Post and Howland (3) and to those maintained by successful commercial rose growers. The rather large yearly decreases in flower production obtained in this study are probably due to the relatively low levels of nitrogen, phosphorus and potassium and to the poor physical condition of the soil. The larger amounts of nitrogen and phosphorus supplied to the 2 pounds of KCl, 2 units of NP plots probably account for the exceptional vigor of these plants.

STEM LENGTH

The data in Table II show that stem length tended to increase with each increment of potassium. Actual stem length in inches (included

stem together with its flower) of all flowers is included in this data. Stems from the plots receiving the larger amounts of potassium, 1 or 2 pounds of KCl with 1 unit of NP and 2 pounds of KCl with 2 units of NP averaged between 1 and 2 inches longer than those from plots receiving lesser quantities of potassium or none. All these differences are highly significant. Although the average length of stems from plots receiving 2 pounds of KCl was greater than that of stems from plots receiving only 1 pound KCl, this difference was not significant. It might be speculated that with further increments of potassium stem length might have been increased still further.

The average length of stems from the plots receiving no potassium was significantly less than that from plots receiving any of the other treatments.

The average length of stems from the plots receiving 0.000, 0.166 or 0.333 pounds of KCl became consistently shorter from year to year. This decrease in length was greatest in the plots receiving no potassium; on these plots the average length of stems dropped from an average of 13.77 inches in 1942–43 to 9.75 inches in 1945–46, a difference of more than 4 inches. A decrease in stem length from year to year was noted also in the plots receiving 0.166 pound or 0.333 pound of KCl, but the difference in stem length between 1942–43 and 1945–46 was only 2.74 inches and 2.42 inches from the two plots respectively.

Although the average length of stems from plots receiving 1 or 2 pounds of KCl with 1 unit of NP was respectively 1.97 inches and 1.72 inches less in 1945–46 than in 1942–43 the decrease in length was not consistent from year to year. The average length of stems from plots receiving 2 pounds of KCl with 2 units of NP was approximately the same in 1945–46 as in 1942–43.

The data indicate that potassium greatly influences the stem length of roses. Increased applications of potassium did not increase the number of flowers produced, but did increase the average stem length significantly. When twice as much nitrogen and phosphorus were supplied, a highly significant increase resulted in production but stem length was not significantly affected.

Stem Weight

The data in Table II show that the green weight of stems tended to increase with each increment of potassium. In these data the stem weight recorded consists of the stem and its flower. Stems were weighed in order that differences in size and quality of the flower and size and heaviness of stem and leaves, if any, would be ascertained. The treatments which differed significantly in the average green weight of stems were the same in most cases as those which differed significantly in average stem length.

The average green weight of stems did not decrease consistently year after year as did the average stem length. The average weight of stems from all plots in 1942–43 was 12.39 grams; in 1943–44 it increased to 13.46 grams, a difference of 1.07 grams, which is highly significant. In 1944–45 the average stem weight was 0.38 grams less

than 1943–44; this difference is not significant. In 1945–46 the average stem weight was 1.37 grams less than in the previous year; this difference is highly significant. Thus, the average stem weight increased significantly in the second year, remained about the same in the third year, and declined sharply in the fourth year.

During the first two years of the study the stem length in inches exceeded the stem weight in grams; during the last two years the stem weight in grams exceeded the stem length in inches. This was true especially of the plots receiving 2 pounds of KCl with 1 unit of NP.

These data indicate that potassium greatly influences the stem weight of roses. Increased applications of potassium did not increase the number of flowers produced but resulted in highly significant increases in the average stem weight. When twice as much nitrogen and phosphorus were supplied, production was highly significantly increased, but stem weight was not significantly affected. Potassium seems to play an important role of lengthening and increasing the weight of a rose stem, an indication of its value in the production of high quality roses.

Weight of All Wood Removed

The data in Table II show that, with the exception of the plots receiving 2 pounds of KCl with 1 unit of NP, the total green weight of all wood removed from the plants tended to increase with each increment of potassium. The weight of all wood cut from the plots receiving 2 pounds of KCl and 1 unit of NP was significantly less than that from the plots receiving only 1 pound of KCl and 1 unit of NP. It should be noted that the plots receiving the former treatment produced stems with greater average weight than did any of the other plots. The fact that significantly fewer flowers were produced by these plots explains why the total wood removed weighed less than that cut from the latter. The total weights of all wood cut from the plots receiving 2 pounds of KCl and 2 units of NP was 68.0 to 121.6 grams greater than that from any of the other plots. These greatly exceed the differences required for significance at the 1 per cent level.

Over the 4-year period in all treatments, regardless of the amount of fertilizers applied, the stem weights made up approximately two-thirds of the total weight removed. The remaining third was made up of hooks, fallen leaves, prunings, and blind wood. Thus the greater total weight from plots receiving 2 pounds of KCl, 2 units of NP is due not only to the weight of the greater number of flowers produced but also to the increased growth of the plant. This difference in growth could be seen readily as the study progressed.

Although the 4-year average showed the ratio of weight of stems and flowers to the weight of all other wood removed to be 2 to 1, this ratio varied greatly with each year of the study. The ratios for the four years beginning with 1942–1943 are 6.7, 1.8, 2.0, and 1.1 to 1 respectively. These different ratios are due largely to the relative amount of pruning done in the various years as well as to variations from year to year in production and weight of the stems and flowers. Very little pruning was done during the first year, a moderate amount during

the second and third years, and at the end of the study the plants were cut back to approximately 12 inches, making the weight of prunings for this last year exceptionally high.

The percentage of blind wood was approximately the same in all treatments.

The data show that significant increases in total weight occurred with increasing increments of potassium up to 1 pound of KCl. The addition of twice as much nitrogen and phosphorus, however, produced a strikingly large increase in total weight as shown by the difference in weights between plots receiving 2 pounds of KCl and 2 units of NP and plots receiving 2 pounds of KCl and 1 unit of NP.

Flower Production by Grades

The data in Tables III and IV show that with each increment of potassium more flowers of the longer and more valuable grades were produced. This tendency is demonstrated most clearly in Table IV, where the percentages of flowers occurring in the various grades are shown. For example, 820 flowers less than 8 inches long or 17 per cent of the total number were produced on plots receiving no potassium; plots receiving 2 pounds of KCl and 1 unit of NP produced only 360 flowers in this grade or 7.5 per cent of the total production. The above plots produced respectively 681 or 14 per cent and 989 or 20.5 per cent of flowers in the 15 to 18 inch grade.

Many more flowers were produced on plots receiving 2 pounds of KCl and 2 units of NP and these flowers were equal in quality to the best quality of flowers produced on any of the other plots.

The data in Tables III and IV indicate the beneficial influence of potassium on quality of flowers produced under the conditions of this experiment.

Summary and Conclusions

Increased applications of potassium to a soil low in available potassium, nitrogen and phosphorus did not increase the number of flowers produced by rose plants growing in that soil. In fact, plants growing in soil supplied with the greatest increment of potassium produced significantly fewer flowers than did plants supplied with lesser quantities. When double the basic quantities of nitrogen and phosphorus were supplied to soil receiving the greatest increment of potassium, however, flower production was greatly increased. Additions of potassium alone to a soil low in nitrogen, phosphorus and potassium did not increase flower production.

In this study when the potassium level was increased from 3 ppm to approximately 15 ppm (as measured by the Spurway test), it was necessary to raise the nitrate level from 3 ppm to approximately 10 ppm and the phosphorus level from 1.5 ppm to 3.5 ppm to secure increased flower production. The roles of nitrogen and phosphorus in the nutrition of the rose seem to be relatively more important in the initiation of flowering shoots than in the later elongation of those shoots.

The quality of flowers produced as measured by stem and flower length and weight increased significantly with each increment of potassium supplied. With each increment of potassium supplied more flowers of the longer, more valuable grades were produced. Quality remained the same when the basic quantities of nitrogen and phosphorus were doubled and applied to the soil receiving the greatest increment of potassium. Adequate amounts of readily available potassium in soils for roses are necessary to produce roses of good size and weight with long, heavy stems. Less than adequate amounts of potassium result in relatively shorter, lighter stems. Potassium apparently performs some important function in the elongation of flowering stems of roses.

Total growth of the plants as measured by the green weight of all flowering and vegetative growth removed increased significantly with each increment of potassium up to 1 pound KCl per 100 square feet per year. This increase in total growth was due largely to the increased stem length and weight of the flowers produced. Total growth was remarkably greater when double the basic quantities of nitrogen and phosphorus were supplied along with the greatest increment of potassium.

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Looking Ahead in Horticulture[1]

By OTIS WOODARD, *Coastal Plain Experiment Station, Tifton, Ga.*

IN the beginning, let me hasten to say that, as retiring chairman, I have no sagacious words of wisdom that would be a sure sign post to a more useful and effective future for this society. And (surprising to you) I confess the possession of no super powers that peculiarly fit me for delving into the future or premising a broader or more effective sphere of activity for the society. I am convinced, however, that men make mistakes and that there are instances where there is no virtue in tradition. The point in question renders this statement irrefutable. It is this: both tradition and the By-laws of this Society require the annual presentation of the retiring chairman's address. Having spent most of my time where you now are, I hesitantly confess that there lingers with me no lasting, constructive impressions of such occasions. At the same time I am conscious of a pall that constantly would hang over me from year to year as I realized that through courtesy I must patiently sit through another long, tedious, retiring chairman's address. And now, looking forward to the betterment of the Society, and after careful consideration, I hereby make bold to submit this suggestion — after your present chairman has concluded his address, that the Society give consideration to the fact that it is now grown-up and has come to the age of discretion; whereby it is fitting that it break with such customs as may become an impediment to progress. But we must move on to more serious phases of the discussion.

In its original concept, horticulture was confined to the culture of gardens and small enclosures. In its modern application, however, it has moved out of such restricted confines and is now in many instances, an enterprise embracing large acreages of open fields and orchards. And in the post war period, it will be only through an elaborate production program that we can supply the constantly increasing demands of our own people and at the same time, rise to the occasion of feeding a hungry world.

And in this connection may we observe that there are those among us who are afraid of growing horticultural crops on an extensive or field crop level. Such a position, if generally accepted, would greatly retard horticultural progress. Contrary to such a concept, we should seize every opportunity to expand the production of horticultural crops on a scale commensurate with the growing demand for such products.

Horticulture as practiced in the past decade and I dare say — as applied today — would not be adequate. If it is true, as we are repeatedly told by both national and world leaders, that food is the key to world peace, then horticultural scientists are in a position to make a contribution of such magnitude as perhaps has never been their privilege in the past. But this world crisis in food shortage is

[1]Address of the retiring chairman of the ninth annual meeting of the Southern Section of the American Society for Horticultural Science, Washington, D. C., February 12, 13, 14, 1948.

immediate and the slow processes of ordinary research would not adequately meet the needs. We, therefore, must go the extra mile, and in addition to our responsibility in basic research, give more freely, to those on the production front, that "know-how" which in many instances is possessed only by the investigator himself, and may be essential to the successful application of newly introduced research findings.

But may we look more closely at horticulture at home. We are constantly reminded that agricultural enterprises are keenly competitive, and as we look more astutely at the problem, there is evidence that the ascendency of one enterprise over another often is not so much a result of merit as of such factors as personality, salesmanship, organization, and propaganda. To illustrate — may I lift up this recent example: excess earnings from war profits have been invested in livestock in Georgia, with the result that there has been a decided increase in beef cattle population in the State. According to a leading livestock man of the area, this increase is not based so much on adaptability or merit, but rather on the fact that it is a fascinating method of dissipating war time earnings. As a result, nevertheless, the swing toward cattle production has been far reaching, with the effect that farm population is diminishing and acre income is being reduced. This type of farm endeavor conceivably could provide higher earnings for a few individuals in a community, but certainly could not add to overall community prosperity. Neither will it, if carried beyond a rather well defined balance, add to state or regional prosperity. The horticulturist's approach, a more dense population, combined with agricultural enterprises having high acre value, constitute a better basis for both individual and community prosperity, and point the way to the production of needed surpluses for the war impoverished nations. Looking still further as our nation passes from adolescence into a period of mature state-hood, there is a growing need for these principles and concepts of horticulture. The inevitable increase in population, together with a corresponding increase in food demand, calls for more intensive cultivation and higher acre production; and we, as horticultural scientists, can contribute immensely toward its accomplishment.

What is our best approach to this higher degree of efficiency? It seems evident that the solution lies, in large measure, in a more closely integrated working relationship with other allied and inter-related sciences. We need not remind you that in many instances, such working relationships are already a reality. Its more universal acceptance, however, would prove the shortest cut to the greatest degree of perfection in horticultural products and likewise, would lift the level of horticultural research to an enviable position of efficiency.

Perhaps at no other time in the history of American horticulture has the acre value of horticultural crops been so high and the relative man-labor requirement so low. This attests the basic value of scientific research. In almost every field, there has been noteworthy progress. We have only to check the records ot research institutions and of this society to find numerous instances where better fruit and

vegetable varieties have resulted from breeding programs designed to develop kinds that will better satisfy the constantly changing production and consumer demands. And yet there is the ever growing need for varieties of more pleasing quality, higher vitamin content, earlier or later maturity, resistance to insects and diseases, and greater adaptability to processing and marketing. Noteworthy among these needs is that of a wilt-resistant watermelon possessing the requirements of an acceptable commercial variety; and there are many other such instances of similar need. In fact, there seems to be no end to the need for new varieties. We therefore, must proceed vigorously in this field.

In the area of plant nutrients, we certainly know more about the fundamentals of plant nutrient requirements than at any time in the history of organized research. Particularly is this true of the effect of minor and secondary elements on the food value and vitamin content of fruits and vegetables. And yet, there remains in this field baffling problems which cry for solution and to which we must give added study. The soil chemist should be a closer ally here.

Perhaps the greatest innovation in the production of agricultural crops has been mechanization, made possible largely by the advent of the farm tractor, and yet horticulture has not shared equally in this. Here scientific research must bridge the gap by doing three things: (a) by making the best possible use of existing equipment; (b) by adapting machinery to the needs of horticultural crops; and (c) by developing varieties that are better adapted to mechanized culture. To illustrate, satisfactory sweetpotato planters and diggers and a vineless commercial variety of sweetpotato would make possible, almost complete mechanization of a crop which now is given to antiquated or near primitive cultural methods. Here we must work more intimately with the agricultural engineer.

Again, we must have a more fundamental knowledge of the soil. We must know better how to coax from it increased yields of superior quality products and concurrently, bring it year by year, to a higher state of productivity. This will require a closer alliance with soil science.

Irrigation is another field into which we in the Southeast are moving slowly, yet one which, when fully embraced, will give heavier yields, higher quality products, will prove an indispensable factor in preventing crop losses and will give added profit. The irrigation engineer is our ally here.

Another innovation in horticultural research within recent years, is regional cooperation. This constitutes a long step forward in evaluating varieties and in both the application and adaptation of experimental findings. The greatest good, however, will come from a more closely integrated, inter-sectional program — and likewise a more intimate working relationship, which in the opinion of the speaker, is certain to become a tangible reality in the near future.

There is another question we should constantly ask ourselves. Is the level of interest in the different phases of horticultural research commensurate not only with the needs but also with the economic

value of the various enterprises? Our recent programs indicate that there is need for additional research in peaches, apples, small fruits, and in all phases of ornamental horticulture. There is particularly a dirth of scientific information in the latter, and future emphasis on these needs should be of sufficient magnitude to effect corrective measures.

And now may we venture a word of caution? It is this: In our zealous pursuit of research, we well-nigh forget, or at least sometimes overlook the fact, that profitable production and efficient utilization are the major objectives of horticultural research. Another conviction of the speaker is that we should avoid making fads of basic research or of principles involved therein. We have ridden the crest of many extremes, some of which are: The parade of minor and secondary plant food elements, hormones, soilless culture, and statistical evaluation of experimental data. These are phases of experimentation which in some instances make their appearance on the stage of research in a flare of fan-fare, with the result that we sometimes allow ourselves to be drawn away from the more basic and fundamental phases of scientific investigations, such as the ever growing demand for better varieties, a better understanding of plant nutrient requirements, methods of increasing soil productivity, the more effective and economical control of insects and diseases, and the more efficient and effective method of processing and marketing horticultural crops. These are the pillars on which a more prosperous horticulture will be built, and we should not allow ourselves to be drawn aside by flares of lesser importance.

Attendance on papers given at the recent American Association for Advancement of Science meeting in Chicago will serve as an index to the level of interest in the various phases of research. To illustrate, eight people sat in on the section devoted to sweetpotato investigations, while papers on chemical weed control were delivered to crowded parlors. Such observations pose the question, are we weary of such old but all important questions as the quest for "better use of the soil" and "a more comprehensive understanding of the nutrient needs of plants"?

Another issue of grave concern to the speaker is that we as horticultural leaders, have failed horticulture to the extent that we have been less effective than leaders in kindred fields, in selling horticulture to undergraduates, with the result that there is now a dirth of scientifically trained research workers in horticultural fields. And it is further complicated by the fact that a majority of the workers now actively engaged in scientific horticultural research fall within the middle or older age groups. It therefore is my duty and likewise yours, to avail ourselves of every opportunity to steer a higher percentage of the more capable undergraduate students now in our colleges and universities into horticultural work. We must improve our technique in inspiring undergraduates to accept our chosen profession as a life career. We must be better evangels of the gospel of horticulture.

In conclusion may we resolve here and now, to join ourselves into

a finer spirit of devotion and loyalty to our honored profession, that through our efforts, there may evolve a more refined type of horticulture, that will give to the people of our nation and of the world finer food, more vitamins, better health, more exquisite flowers, more beautiful gardens, and also make it possible for those who give themselves to horticultural pursuits, to have a more lucrative share, or at least a more adequate portion of material wealth, and likewise a more abundant life. Ours is an enviable heritage. It is our responsibility — and likewise our privilege, to add to the sum-total of horticultural knowledge, as we pass the responsibility of horticultural leadership on to those who shall follow.

Cooperation in Vegetable Research

(PRESIDENTIAL ADDRESS)

By JAMES E. KNOTT, *University of California, Davis, Calif.*

COOPERATION in research is a delicate plant which must be nourished by the minds and talents of men of varied training and experience — men of unselfish attitude. If this plant is to thrive, there must be an amelioration in different points of view. We must practice the motto of Sigma Xi, "Companions in zealous research". It is my purpose to suggest how an investigational program with vegetable crops can be developed on a cooperative basis.

The organization of research with vegetables presents a somewhat different situation from that which prevails with fruits. Vegetable crops are more numerous and more diversified. In California alone, 23 vegetables are of sufficient importance for the Crop Reporting Service to tabulate the annual acreage by counties. Then, too, a vegetable grown for seed may require different ecological conditions from a vegetable intended for the market or for processing.

Let us consider the scheme followed in developing a research program with vegetables in California and the part that cooperation must play in its functioning. Here is a state which if transplanted to the Atlantic Coast would extend from Charlestown, Massachusetts, to Charleston, South Carolina. But climatically California extends much further. At Tulelake, with a 4,000 foot elevation near the Oregon border, vegetables are subject to occasional summer frosts. In the Imperial Valley, below sea level and close to Mexico, the occasional winter frosts are the growers' concern. In the central and south coastal districts with relatively mild climates, the diurnal fluctuations in temperature are about 20 degrees F. Just over the coastal range lie the San Joaquin and Sacramento valleys, in many parts of which from spring to fall there is a 40 to 50 degrees F difference between day and night temperatures.

Under these conditions a research program involves year-round production. There is no snow-bound period which the staff can devote to writing reports and preparing publications. It is easy to see how ambitious staff members can overload themselves.

We think of vegetables, not as spring or summer crops, but as cool-season or warm-season products. This distinction helps us greatly in planning our work. It seems best for Experiment Station workers to concentrate on the more specialized breeding problems, such as those in which we seek resistance to diseases or insects. Most of the less specialized general improvement work is therefore left to the seed companies who are interested in making their stocks as excellent as possible in order to enjoy a competitive advantage.

The number of projects to be considered in any breeding program depends on the immediate pressing need and on predicted future disease problems. Some growers would like to have Experiment Station workers serve as crystal-gazers or, one might almost say, prophets of doom. They would have us develop, far ahead of time, varieties of

vegetables resistant to diseases which may someday become limiting factors in a given area. This attitude of the industry, although complimentary, gives research workers credit for abilities that they do not possess. To be sure, any vegetable research program must be kept fluid enough so that urgent problems which suddenly arise can be investigated. Even then we must consider the necessity of the problem, the value of the particular segment concerned in relation to the whole truck crop industry, and the feasibility of including such research in our program.

In organizing the breeding program for each individual, we have paired cool-season crops with warm-season crops. Thus, one man tackles asparagus and canning tomatoes; another onions and potatoes with cantaloupes and watermelons; and yet another spinach and carrots with peppers and market tomatoes. Celery and lettuce could be paired with snap beans and sweet corn if we need to start breeding of these latter two crops, although celery and lettuce are grown somewhere in California in every month. These fields of research might be said to be vertical lines of endeavor.

Then, to cut across all the breeding projects, we have a man who can help with any cytogenetical aspects that may arise. Male sterility, for example, has proved to be important with several of our crops. The hybridizing of our cultivated species with wild species used as sources of disease resistance presents cytogenetic problems that must be understood if we are to improve the breeding program.

The men who are responsible for these research activities are primarily trained in genetics, sometimes with plant pathology as an auxiliary discipline. They are not expected to handle physiological or anatomical problems with these crops.

After vegetable varieties have established their merit, we must develop the best methods for growing and handling them. These aspects, biochemical, physiological, and anatomical in nature, concern all established vegetable varieties and therefore constitute other horizontal lines of investigation. So next we cut across all breeding programs with men trained in plant anatomy. They are helpful in coping with differences between breeding plot cultures — differences that might or might not adapt the crop for quick-freezing or other special uses. The anatomists cooperate with the men concerned with some of the other horizontal lines of work whenever environmental, cultural, or post-harvest handling may influence differential growth of plant tissues.

There is obvious necessity for horizontal lines of research that cut across all crops as to their fertility requirements, need for irrigation, and other physiological responses encountered in their culture, their harvesting, or their post-harvest handling. Another horizontal field of activity is the effect of our widely differing climates and soils on the nutritive value of vegetables, and the effect of stage of maturity at harvest upon food value. With this work it is possible to coordinate effectively any studies of grades and quality that seem desirable.

Vegetable seed production is a highly important segment of the truck crops industry of California — a segment that has special physi-

ological requirements. Here again is a horizontal field of research cutting across all studies of vegetables. Workers in this field develop new techniques in seed production and improve the quality of seeds.

Cooperation Within the Division

Thus, research with vegetables might be likened to a grid in which one set of approaches intersects another set. To handle this gridwork of research, four men are charged with the vertical fields and nine men with the horizontal ones. Cooperation, the strengthening bond at the intersections, must be the keynote or else our framework would fall apart. One cannot force cooperative effort, because personalities invariably play a part; but when cooperation is traditional, the atmosphere created does much to facilitate teamwork. All these staff members are located at Davis. The daily contact of this whole group, which is planning and conducting the research program, leads to cooperation through the exchange of ideas and the integration of the investigations. This situation would not be possible if the staff were scattered all over the state at permanent field stations. Such dispersion would isolate the men, and they would tend to stagnate — would lack the stimulus that comes from constant association and cooperation with other scientific workers.

For our program, two important laboratory set-ups are essential. One provides the routine chemical analyses necessary to the many lines of horizontal research of a physiological or biochemical nature. The other is a microtechnique laboratory for work on the problems encountered in any of the cytogenetical or anatomical research. The senior technician in charge of each laboratory must set up a calendar that will serve the needs of all staff members impartially — thus furthering the cooperative spirit.

In research with vegetables our principal laboratories are outdoors. Ultimately the entire state must become our laboratory. We must be able to handle plantings of any segregating material from our breeding plots which appears to have promise but which needs to be observed and selected under various climatic conditions. We must be prepared to supervise closely widely scattered experiments with fertilizers or with other cultural techniques; to repeat any given experiment in many places with differing climates; and to attack the peculiar problems of any given area.

In order to meet these needs, substations on wheels have been instituted. Though they are on wheels, we also have land available on loan or lease in each area for work that should continue on the same spot for several years. The University does maintain a field station in which we share in the Imperial Valley. The area covered by each of these mobile men may include several counties. Thus one man works in the northern section near the Oregon border. The staff at Davis can handle the lower Sacramento Valley. One man has responsibility for the Delta — that important group of islands and surrounding territory at the confluence of the Sacramento and San Joaquin rivers. The southern end of the San Joaquin Valley from Fresno to Bakersfield is also important. The man there can readily cross the mountains into

Los Angeles and Ventura counties. The central coast area from Santa Cruz to Santa Barbara, including the important Salinas Valley, is another unit with a characteristic climate. The Imperial and Coachella valleys in the far south are another distinct area. Fortunately or unfortunately, the summers there are too hot for vegetable production; but it is a short run to the south coastal district of San Diego, Orange and Los Angeles counties. By careful planning, the needs of the staff for plots in those coast counties can be handled throughout the year by the man we have in the Imperial Valley.

Like the technicians in the laboratories, these roving field men must organize their work. They must know the limitations imposed by distance and the labor required for each type of plot so that all staff members needing to extend their effort into that area will have equal opportunities. They come back to Davis periodically to go over plans with the staff; and since staff members are seeing them constantly at the plots, the program is kept fluid.

Cooperation with the Extension Service

These field men must work closely with the County Extension Services in their respective areas to keep abreast of problems which should be referred to the staff, to obtain the help of the Farm Advisors in finding cooperators, and to provide, from the local experiments, information which these extension men can pass on to their growers. Often one of our experimental plots can serve the Extension Service nicely as a focal point for demonstration meetings.

Cooperation is the key to our relationship with the county extension services and to the location of adequate plots in growers' fields. The emphasis in California is on specialists in each county, with only a few state-wide subject matter specialists to keep them abreast of new developments. Thus the county extension men are able to manage test plots of various sorts which in other states might have to be conducted by experiment-station men. Those test plots with vegetables are often planned and carried out in cooperation with our staff members and with the truck-crops extension specialist. The results augment the fun of data constantly being accumulated on variety and cultural problems. Moreover, the truck-crops specialist who is headquartered with us at Davis cooperates very closely with the research staff on several experimental projects. His presence as one of our group is important in keeping him aware of research developments and in furthering the whole cooperative relationship with the extension workers in the counties.

Cooperation with Other Divisions

It is axiomatic in the California Experiment Station that when a problem arises the facilities of all divisions that can contribute to a solution are directed on it. For example, water relations of vegetables are studied in cooperation with the Division of Irrigation, and the development of new machinery or equipment for use in the harvesting or handling of vegetables is shared with the Division of Agricultural Engineering. In the study of pelleted vegetable seed, which might

involve the inclusion of fungicides in the pelleting material, and of course would require precision planting machinery, the divisions of Plant Pathology, Agricultural Engineering, and Truck Crops would cooperate.

Besides this somewhat formal type of cooperation, we receive much incidental help from other divisions. The plant pathologists not only provide us with the inoculum for treating progenies in which we are seeking disease resistance, but also later help us in surveying the results, to make certain that we have the resistance we seek. Without such earnest cooperation our work would be seriously handicapped.

Cooperation with State Agencies

The regulatory aspects of the vegetable industry are handled in California by State agencies operating under standardization laws. The results of our work on some of the horizontal lines of research provide data on which these standards can be based. It has been possible to cooperate, for example, on problems of seed germination, the establishment of grades and maturity of vegetables, and the advisability of licensing certain agricultural chemicals for sale in the state.

Cooperation with Federal Agencies

Cooperation between state and federal agricultural research agencies is desirable under present-day conditions. Yet I am concerned sometimes by the way it functions. Possibly this is because of the distance that may separate those responsible for the direction of the research. The emphasis may suddenly change because of trends in the project as it is conducted in other parts of the country. This change may upset the plans and schedule which the man on the state end of the cooperative deal has made. It is true that sudden shifts are more likely to occur in some types of research than in others. In spite of certain of these irritations we have had in general a very happy cooperative relationship with the United States Department of Agriculture, especially on some of our projects.

In the interstate shipment of vegetables we do not lose interest as soon as the vegetables cross the California state line. We want to know in what condition they arrive at the terminal market and how the consumer accepts them. The United States Department of Agriculture, with men stationed in various markets, can be of great assistance in evaluating market quality. Thus a cooperative project is the answer. Our men have some ideas of their own as to when and what transit conditions should be studied. They should be equal partners in the planning and timing of all studies of the movement of California vegetables.

It is desirable to have nation-wide breeding programs with vegetables so that greater efficiency can be obtained in the development of progenies. This procedure, however, can easily become at odds with the current system of having staffs of well-trained men in the State Experiment Stations. Each worker's professional advancement depends upon his growth in his chosen field of science. Certainly a reasonable amount of checking of progenies needs to be done with the

expectation of finding varieties or strains with local adaptation. But if the work is to be truly cooperative, a definite effort should be made to see that the men in the states share equally in the planning and have some aspects of the basic genetical work which they can develop on their own.

In relation to state and federal cooperative research, one cardinal point must never be forgotten. Each party to the effort must stress the fact that the work is cooperative. He needs to live and talk cooperation. Even though one group of growers or shippers may at first recognize the cooperative nature of a given program of research, the clientele will change and the awareness will disappear as time passes.

If an Experiment Station is to obtain funds from the legislature for the conduct of its work, growers throughout the state must be made to realize that both the United States Department of Agriculture and the Experiment Station are involved in the research under whatever cooperative memoranda of understanding may exist, and that the work is not done solely by either agency.

In my judgment, the policy of the United States Department of Agriculture should be to refrain from entering a State to conduct research except at the request of and in cooperation with the Experiment Station of that State. Even then the work should be only on problems of national or regional significance. I think that in general this is the policy, although there is some deviation from it. The work may start in that way, but over a period of years the initial basis can easily become altered. With changing personnel we sometimes find State and Federal men working independently on much the same problems.

The Agricultural Research Study Committee created by an Act of the California Legislature recommends in its report that "under a coordinated program of agricultural research by the Federal and State Governments having to do with California problems there should be a minimum amount of overlapping in order to effect economies of both federal and state expenditures". To accomplish this aim, planning and cooperation of the highest order are required.

Cooperation with the Industry

In any well-rounded research program the contacts maintained with various segments of the agricultural industry play no small part. We have this type of close cooperation with the Canners League, the Fertlizer Association, the Seed Association, the Frozen Food Processors Association, and various groups of growers, shippers, and other distributors. Many of these groups have research committees for implementing this cooperation. They know our program, help us anticipate their needs for research, encourage us, and frequently back us with funds.

Cooperation with the Taxpayers

Then there is the matter of cooperation with the taxpayer. We whose work is supported by public money have an obligation to render service where it is needed. The results of our research are not our

own personal property, but a trust which we are obligated to make available as soon as possible in order that others may benefit. Cooperation with the taxpayer implies also that our research will be conducted efficiently. This means that the teamwork already mentioned will be utilized to the utmost in making the work comprehensive and productive.

World-wide Cooperation

A State agricultural research program has two principal functions. One is direct service to the agricultural industry, and the other is service to science. No hard and fast line can be drawn to determine how much time should be devoted to each. If we work only on the immediate problems confronting the vegetable industry, we may in time exhaust the supply of new basic information and concepts to which we can turn when a practical problem faces us. We must push back constantly the frontiers of knowledge. Whenever a researcher in attacking a practical problem sees a side line which may develop basic facts, he should follow it up to see whether it does elucidate some new knowledge. This is cooperation with the broad field of science which knows no national boundaries. Who can tell for whom this bit of information may serve as clue to the solution of a vexing problem? Vital and basic, or applied and fundamental research, whichever terminology you wish to us, should go hand in hand. And why should we not expect that this should be so, considering the high calibre of training in scientific disciplines which we now expect our research personnel to have?

Conclusion

This leads me to my final point — namely, that training in the sciences is becoming more and more specialized. The literature is now so voluminous that no one man can keep abreast of all the new developments that might apply to the solution of problems in vegetable production. The teamwork of many men is needed to serve properly the vegetable industry of any State.

Only through the cooperation of men of good will can the increasingly complex problems of the future be solved. Where can a start be made better than by us who are concerned with helping a key industry — an industry that àids in nourishing the peoples of the world?

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INDEX

PAGE

Air purification, in apple storage 205, 219
Alban, E. K., and Ford, H. W., paper by 183
Ford, H. W., and Howlett, F. S., paper by............ 385
Alderman, D. C., paper by...... 149
Alger, John, and Kiplinger, D. C., paper by 478
Allen, F. W., and Claypool, L. L., paper by 192
Angelica seed, storage and germination of 471
Anthesis, and nutrient-element balance in tomato flowers...... 347
Anthony, R. D., Frear, D. E. H., Haskins, A. L., and Hewetson, F. N., paper by........ 61
Antirrhinum majus, resistance to rust in 481
Apple sports, use in breeding.... 130
Apple storage, air purification in 205, 219
Apples, chemical thinning of.... 164
color index of nitrogen content of leaves of............... 57
frost injury to............... 157
maturity indices for.......... 176
Ascorbic acid, content of peach varieties 143
in strawberries in Mississippi.. 251

Bacterial leaf spot, mineral nutrition of peach trees with reference to 47
Bacterial soft rot, on potatoes, effect from washing in deep vats 325
Bacterial spot, resistance in peppers to 336
Bailey, J. S., paper by.......265, 299
Baking sweet potato, tests in Hawaii 307
Barger, W. R., and Dewey, D. H., paper by 325
Batjer, L. P., and Thompson, A. H., paper by........... 164
Beach, G., and Mussenbrock, A., paper by 487
Beans, effect of hormone sprays on 448
Beckenbach, J. R., and Burgis, D. S., paper by............ 461
Beets, effect of sodium salts and seeding on yield and color of 398
Biale, J. B., paper by........... 187
Blackhurst, H. T., paper by..... 510

PAGE

Blackmon, G. H., Lagasse, F. S., and Potter, G. F., paper by.. 107
Blindness, in roses............. 490
Blossom thinning, effect on peach fruit bud hardiness.......... 112
Blueberries, control of mummy berry on 299
Rabbiteye, propagation of.... 289
Boller, C. A., and Roberts, A. N., paper by 501
Boron, effect on peach trees..... 88
Boynton, D., Compton, O. C., and Fisher, E., paper by........ 40
Breeding, Cucumis melo........ 399
tung 81
with giant apple sports........ 130
Bregger, J. T., paper by......... 141
Brightwell, W. T., paper by.... 289
Brooks, R. M., paper by........ 213
Brown, J. G., Lilleland, O., and Jackson, R. K., paper by.... 1
Brown, R. T., Painter, J. H., and Drosdoff, M., paper by...... 19
Burgis, D. S., and Beckenbach, J. R., paper by............. 461
Bush lima beans, effect of DDT on 453

Calcium, in citrus flowers....... 7
in leaves 1
Calimyrna fig, use of growth regulators to produce parthenocarpic fruit of............. 236
Campbell, R. W., paper by...... 117
Caprifigs, parthenocarpy in...... 233
Capsicum pubescens, species of... 331
Carnations, effect of nitrogen and potash on 487
Celery plant growth, correlation of soil test with........... 443
Chadwick, L. C., and Galle, F., paper by 517
Chaplin, C. E., paper by......... 121
Chemical thinning, of apples.... 164
Chinese Brassicas, effect of bud pollination on fertility and fruit of 435
Chinese wing-nut, rootstock for Persian walnut 103
Chrysanthemums, shading of.... 478
Citrus flowers, potassium, calcium and magnesium content in... 7
Citrus fruits, respiration in relation to metabolism of fungi.. 187
specific gravity of........... 245
Claypool, L. L., and Allen, F. W., paper by 192
Cold injury, to dormant buds of tung 115

PAGE

Color, Federal canning tomato grade, relation to horticultural color determinations...... 415
 index of nitrogen content of apple leaves 57
 leaf, as measure of nitrogen status of fruit trees........... 40
Compton, O. C., Boynton, D., and Fisher, E., paper by........ 40
Condit, I. J., paper by........... 233
Cranberries, keeping quality of pre-packaged 257
Crane, J. C., paper by........236, 237
Cucumis melo, inheritance of.... 399
Cucurbita moschata, adapted to South 430
Cucurbita pepo, seed, use as vegetable fat, protein, confection and sandwich spread........ 403
Culbert, J. R., and Wilde, E. I., paper by 528
Curtis, L. C., paper by.......... 403
Cytogenic studies, on Rosa Rubiginosa 510

Darrow, G. M., Gibson, R. A., Toenjes, W. E., and Dermen, H., paper by.............. 130
Dates, relative humidity for storing 173
Davis, J. F., and Lawton, K., paper by 443
DDT, effect on bush lima beans.. 453
Dermen, H., Darrow, G. M., Gibson, R. A., and Toenjes, W. E., paper by........... 130
Dewey, D. H., and Barger, W. R., paper by 325
Dickey, R. D., paper by......... 115
Drosdoff, M., and Lagasse, F. S., paper by 11
 Neff, M. S., and Sharpe, R., paper by 97
 Painter, J. H., and Brown, R. T., paper by............ 19
Dunham, C. W., and Roberts, R. H., paper by........... 525
Durham, fall-bearing red raspberry, and spur blight.......... 263

Edgerton, L. J., paper by........ 112
Embryos, Solanum nigrum, culture of 343
English holly, pollination of..... 501
Esselen, W. B., Jr., Hayes, K. M., and Fellers, C. R., paper by.. 257

Fagan, F. N., Thomas, W., and Mack, W. B., paper by...... 47
Fellers, C. R., Hayes, K. M., and Esselen, W. B. Jr., paper by 257
Fertilizers, effect on sweetpotatoes 317

PAGE

Fig varieties, fruit growth of.... 237
Fisher, E., Boynton, D., and Compton, O. C., paper by......... 40
Flame method, determination of calcium and magnesium in leaves by 1
Flower type, inheritance in Muscadine grape 276
Flowering, of Veitch gardenia... 475
Flowers, olive, seasonal incidence of staminate and perfect..... 213
Ford, H. W., and Alban, E. K., paper by 183
 Alban, E. K., and Howlett, F. S., paper by............. 385
Frazier, W. A., Kikuta, K., and Hendrix, J. W., paper by.... 341
Frear, D. E. H., Anthony, R. D., Haskins, A. L., and Hewetson, F. N., paper by........ 61
Freezing, artificial, of peach fruit buds 121
Frost injury, to apples.......... 157
Fruit growth, of four fig varieties 237
Fruits, citrus, specific gravity of.. 245
 parthenocarpic, morphological development of 226
 storage and ripening response, to post-harvest treatment with growth regulators 159
Fusarium wilt, sweetpotato from Tinian Island resistant to... 304

Galle, F., and Chadwick, L. C., paper by 517
Gardenia, flowering of.......... 475
Gerhardt, F., and Smith, E., paper by 159
Germination, of Angelica seed... 471
Gibson, R. A., Darrow, G. M., Toenjes, W. E., and Dermen, H., paper by 130
Grape root-rot, control in solution culture 279
Grape vines, Muscadine, magnesium injection in......... 283
Grapes, green wood grafting on 294
 Muscadine, inheritance of flower type in................. 276
Green wood grafting, on grapes.. 294
Greenhouse tomatoes, effect of cultural practices on respiration rate of.............. 385
Greenleaf, W. H., paper by...... 430
Growth, fruit, of four fig varieties 237
 of hydrangeas 525
Growth regulators, to induce parthenocarpic Calimyrna figs.. 236
 storage and ripening response of western-grown fruits to post-harvest treatment with.. 159

PAGE

Haas, A. R. C., paper by........ 7
Hall, C. B., paper by........... 343
Hardiness, peach fruit bud, effect of blossom thinning on...... 112
Harmon, F. N., and Snyder, E., paper by 294
Hartman, J., and Oesterle, E., paper by 383
Harvesting methods, effect on keeping quality of peaches... 149
Haskins, A. L., Frear, D. E. H., Anthony, R. D., and Hewetson, F. N., paper by......... 61
Hawaii, baking sweet potato tests in 307
Hayes, K. M., Fellers, C. R., and Esselen, W. B. Jr., paper by 257
Heiser, C. B., and Smith, P. G., paper by 331
Hendrix, J. W., Frazier, W. A., and Kikuta, K., paper by.... 341
Herbicides, effect on weeds and root-knot in vegetable seedbeds 461
Hewetson, F. N., Frear, D. E. H., Anthony, R. D., and Haskins, A. L., paper by............ 61
Hewitt, W. B., and Williams, W. O., paper by........... 279
Hibbard, A. D., paper by........ 131
Holly, English, pollination of.... 501
Hormone-insecticide-fungicide mixtures, effect on tomatoes 365
Hormone sprays, effect on snap beans 448
Horsfall, F., and Shear, G. M., paper by 57
Horticulture, looking ahead in... 537
Howlett, F. S., Alban, E. K., and Ford, H. W., paper by...... 385
Hoyle, B. J., paper by........... 407
Hughes, M. B., paper by........ 399
Hybrid tomato seed, production in greenhouse 350
functionally sterile flower mutant in 355
Hydrangeas, growth and pinching of 525

Ilex Aquifolium, pollination of.. 501
Irrigation, effect on sweetpotatoes 317
Isbell, C. L., paper by.......... 368

Jackson, R. K., Brown, J. G., and Lilleland, O., paper by...... 1
Johnson, W. A., and Ware, L. M., paper by 313, 317
Joley, L. E., and Whitehouse, W. E., paper by........... 103

Kamp, J. R., paper by.......... 490
Keeping quality, of pre-packaged cranberries 257
Kikuta, K., Frazier, W. A., and Hendrix, J. W., paper by... 341
Kilby, W. W., paper by......... 81
Kimbrough, W. D., and Miller, C. A., paper by............ 322
Kiplinger, D. C., and Alger, John 478
Knott, J. E., paper by......... 542
Kohlrabi, effect of sprout preventive treatments in storage... 368
Kosar, W., and Thompson, R. C., paper by 441

Lagasse, F. S., and Drosdoff, M., paper by 11
Potter, G. F., and Blackmon, G. H., paper by............ 107
Lambeth, V. N., paper by....... 347
Larson, R. E., and Paur, S., paper by 355
Lawton, K., and Davis, J. F., paper by 443
Leaf nitrogen, as measure of nitrogen status of fruit trees... 40
Lee, S. H., paper by........... 435
Lemons, effect of emanations of Penicillium digitatum at different stages of ripeness on.. 187
Lettuce, nutrient-element balance and growth of............. 464
vernalization and seed stem development in 441
Lilleland, O., Brown, J. G., and Jackson, R. K., paper by.... 1
Lima beans, effect of DDT on... 453
Lott, W. L., paper by.......... 283

MacGillivray, J. H., paper by.... 415
Mack, W. B., Thomas, W., and Fagan, F. N., paper by...... 47
Magnesium, in citrus flowers.... 7
in leaves 1
Magnesium injection, in Muscadine grape vines............ 283
Mann, L. K., paper by.......... 226
Marshall, R. E., Paul, P., Ohlsen, M., and Robertson, W. F., paper by 391
Martin, J. A., paper by......... 336
Maturity indices, for McIntosh apples 176
McCartney, J. S., paper by...... 271
McElwee, E. W., paper by...... 475
McWhirter, L., and Overcash, J. P., paper by............ 251
Mehlquist, G. A. L., and Rahmani, R., paper by.......... 481
Melon, breeding of.............. 399
Metabolism of fungi, respiration of citrus fruits in relation to 187

PAGE

Miller, C. A., and Kimbrough, W. D., paper by............ 322
Mineral nutrition, of peach trees.. 47
Modified atmosphere, effect on storage life of pears........ 192
Morphological development, of parthenocarpic fruits 226
Mulches, effect on woody ornamental plants 517
Mullison, W. R., paper by...... 467
Mummy berry, of blueberries, control of 299
Mussenbrock, A., and Beach, G., paper by 487
Mutant, sterile, in tomato, value in hybrid seed production.... 355

Naphthaleneacetic acid, effect on rest in raspberry........... 271
Neff, M. S., and Painter, J. H., paper by 75
  Drosdoff, M., and Sharpe, R., paper by 97
Nematode control, in nutriculture 467
Nitrogen, content of apple leaves 57
  effect on carnations........... 487
  effect on sweetpotato vines and roots 313
  effect on tung trees..........19, 25
Nitrogen status of fruit trees, leaf nitrogen and color as measure of 40
Nutriculture, nematode control in 467
Nutrient-element balance, and growth of lettuce........... 464
  and time of anthesis in tomato flowers 347
Nutrition of tung trees.......... 11

Oesterle, E., and Hartman, J., paper by 383
Ohlsen, M., Marshall, R. E., Paul, P., and Robertson, W. F., paper by............ 391
Olive flowers, seasonal incidence of perfect and staminate.... 213
Onion curing, comparison of storage losses from............ 407
Organic materials, effect on sweetpotatoes 317
Ornamental plants, effect of mulches and crops on growth of 517
Overcash, J. P., and McWhirter, L., paper by............... 251

Paddock, E. F., paper by........ 365
Painter J. H., and Neff, M. S., paper by 75
  Drosdoff, M., and Brown, R. T., paper by 19

PAGE

Parthenocarpic Calimyrna figs, effect of growth regulators on 236
  fruits, morphological development of 226
Parthenocarpy in caprifigs....... 233
Paul, P., Marshall, R. E., Ohlsen, M., and Robertson, W. F., paper by 391
Paur, S., and Larson, R. E., paper by 355
Peach fruit buds, artificial freezing tests of................ 121
  hardiness, effect of blossom thinning on 112
Peach trees, effect of pruning on 131
  mineral nutrition of, with reference to bacterial leaf spot... 47
  potassium content of.......... 61
  response to boron............. 88
Peach varieties, ascorbic acid content of 143
Peaches, effect of harvesting methods and container performance on keeping quality of 149
  incompatibilities on seedlings of Yunnan understock 141
  survived minus thirty-two degrees Fahrenheit 117
Pears, effect of modified atmospheres on storage life of..... 192
Penicillium digitatum, effect of emanations on lemons at different stages of ripeness..... 187
Peppers, bacterial spot resistance in 336
  species of 331
Persian walnut, propagated on Chinese wingnut rootstock.. 103
Phosphorus, effect on tung trees 25
Picking, effect of frequency of, on yield and returns of tomatoes 383
Pinching, of hydrangeas......... 525
Plant training, effect on production of F_1 hybrid tomato seed in greenhouse 350
Pollination, bud, effect on fertility and fruit of Chinese Brassicas 435
  effect on production of F_1 hybrid tomato seed in greenhouse 350
  of English holly............. 501
Poole, C. F., paper by.......... 307
Porto Rico sweet potato, top system of 311
Potash, effect on carnations..... 487
Potassium, content of peach trees 61
  effect on roses............... 528
  effect on tung trees..........19, 25
  in citrus flowers............. 7

PAGE

Potatoes, bacterial soft rot, resulting from washing in deep vats 325
effect of sprout preventive treatments in storage 368
Potter, G. F., Lagasse, F. S., and Blackmon, G. H., paper by.. 107
Pre-packaged cranberries, keeping quality of............ 257
Pressure unit, multiple chamber, for respiration studies....... 183
Propagation of Rabbiteye blueberry 289
Pruning, effect on peach trees... 131
Pterocarya stenoptera rootstock for Persian walnut......... 103
Pumpkins, adapted to South..... 430

Quartz spectrophotometer, determination of calcium and magnesium in leaves by......... 1

Rabbiteye blueberry, propagation of 289
Rahmani, R., and Mehlquist, G. A. L., paper by.......... 481
Randhawa, G. S., and Thompson, H. C., paper by............ 448
Rasmussen, E. J., and Yeager, A. F., paper by............ 157
Raspberry, Durham, fall bearing and spur blight problem..... 263
effect of a-naphthaleneacetic acid on rest of................. 271
red, rest period in........... 265
Relative humidity for storing dates 173
Research, vegetable 542
Respiration of citrus fruits, relation to metabolism of fungi.. 187
Respiration rate of tomato fruit, effect of greenhouse cultural practices on 385
Respiration studies, multiple chamber pressure unit for 183
Rest, in raspberry, effect of a-naphthaleneacetic acid on.... 271
Rest period, in red raspberries... 265
Richards, M. C., and Yeager, A. F., paper by............ 263
Ripening response, of western-grown fruits to post-harvest treatment with growth regulators 159
Roberts, A. N., and Boller, C. A., paper by 501
Roberts, R. H., and Dunham, C. W., paper by........... 525
Robertson, W. F., Marshall, R. E., Paul, P., and Ohlsen, M., paper by 391
Root-knot, control in vegetable seedbeds with herbicides..... 461

PAGE

Root-rot, grape, control in solution culture 279
Rosa rubiginosa, cytogenic studies on 510
Roses, blindness in.............. 490
effect of potassium on......... 528
Rust, resistance in snapdragon... 481
Rygg, G. L., paper by........... 173

Sayre, C. B., and Vittum, M. T., paper by 398
Schroeder, R. A., paper by...... 464
Scion and stock combinations, with Spy 227............... 137
Scott, L. E., paper by........... 393
Seed, Cucurbita pepo, use as vegetable fat, protein, confection and sandwich spread........ 403
tomato hybrid, value of functionally sterile flower mutant in production of............ 355
Seedbeds, vegetable, herbicides for 461
Seeding, effect on yield and color of beets 398
Seedling rootstocks, effect on tung clones 97
Seed stem, development in lettuce 441
Shading, of chrysanthemums..... 478
Sharpe, R., Neff, M. S., and Drosdoff, M., paper by...... 97
Shear, G. M., and Horsfall, F., paper by 57
Sitton, B. G., paper by.......... 25
Smith, E., and Gerhardt, F., paper by 159
Smith, P. G., and Heiser, C. B., paper by 331
Smock, R. M., paper by......... 176
and Southwick, F. W., paper by 219
Snap beans, effect of hormone sprays on 448
Snapdragon, resistance to rust in 481
Snyder, E., and Harmon, F. N., paper by 294
Sodium salts, effect on yield and color of beets............. 398
Soil, effect on growth of woody ornamental plants 517
Soil test, correlation with celery plant growth 443
Solanum nigrum embryos, culture of 343
Southern tomato exchange program 375
Southwick, F. W., and Smock, R. M., paper by............ 219
Specific gravity of citrus fruits.. 245
Spectrophotometer, quartz, determination of calcium and magnesium in leaves by........ 1
Sports, giant of apple, use in breeding 130

PAGE

Sprout prevention, effect on kohlrabi, potatoes, sweetpotatoes and turnips in storage....... 368
Spur blight, and Durham fall-bearing red raspberry....... 263
Squash seed, use as vegetable fat, protein, confection, and sandwich spread 403
Stair, E. C., and Wolf, E. A., paper by 350
Steinbauer, C. E., paper by...... 304
Stock, and scion combinations with Spy 227............... 137
 Yunnan, peach incompatibilities on seedlings of............ 141
Storage, apple, air purification in 205, 219
 of Angelica seed............. 471
 of vine-ripened tomatoes....... 393
 onion, comparison of methods of curing on losses in.......... 407
 pears, effect of modified atmospheres on 192
 response of western-grown fruits to post-harvest treatment with growth regulators 159
Strawberries, ascorbic acid content of, in Mississippi....... 251
Sun, effect on keeping of sweet potatoes 322
Sweet potato, baking tests in Hawaii 307
 effect of exposure to sun on keeping of 322
 effect of sprout preventive treatments in storage 368
 Tinian Island, resistant to fusarium wilt 304
 top system of bunch Porto Rico 311
 vines and roots, effect of nitrogen on 313

Taylor, C. A., paper by......... 471
Thinning, blossom, effect on peach fruit bud hardiness......... 112
 chemical, of apples 164
Thomas, W., Mack, W. B., and Fagan, F. N., paper by...... 47
Thompson, A. H., and Batjer, L. P., paper by............ 164
Thompson, H. C., and Randhawa, G. S., paper by............ 448
Thompson, R. C., and Kosar, W., paper by 441
Tinian Island, sweetpotato, resistant to fusarium wilt..... 304
Toenjes, W., Darrow, G. M., Gibson, R. A., and Dermen, H., paper by 130
Tomato, color grade, Federal canning 415

PAGE

 exchange program, southern... 375
 flower mutant, sterile, value in hybrid seed production...... 355
 flowers, nutrient-element balance and anthesis in............ 347
 improvement, climate and time in 341
 seed, F_1 hybrid, production in greenhouse 350
Tomatoes, effect of frequency of picking on yield and returns of 383
 effect of hormone-insecticide-fungicide mixtures on....... 365
 greenhouse, effect of cultural practices on respiration rate of 385
 storage of 393
Top system of bunch Porto Rico sweet potato 311
Tung, breeding of............. 81
 cold injury to dormant buds of 115
 clones, effect of seedling rootstocks on 97
Tung trees, effect of nitrogen, phosphorus, and potash fertilizers on 25
 effect of potassium and nitrogen on 19
 nutrition of 11
 trained to vase form.......... 75
 variability of fruits of......... 107
Turnips, effect of sprout preventive treatments in storage.... 368
Turrell, F. M., paper by........ 245

Understock, Yunnan, peach incompatibilities on seedlings of 141

Van Doren, A., paper by........ 205
Veerhoff, O., and Williams, C. F., paper by 88
Vegetable seedbeds, herbicides for control of weeds and root-knot 461
Vegetables, effect of holding treatments prior to canning on vitamin content and palatability of 391
 research in 542
Veitch gardenia, flowering of.... 475
Vernalization, in lettuce 441
Vitamin content of vegetables, effect of holding treatments prior to canning on......... 391
Vittum, M. T., and Sayre, C. B., paper by 398

Ware, L. M., and Johnson, W. A., paper by 313, 317
Weeks, W. D., paper by......... 137

PAGE

Weigel, C. A., and Wester, R. E., paper by 453
Wester, R. E., and Weigel, C. A., paper by 453
Whitehouse, W. E., and Joley, L. E., paper by 103
Wilde, E. I., and Culbert, J. R., paper by 528
Williams, C. F., and Veerhoff, O., paper by 88
Williams, W. O., and Hewitt, W. B., paper by 279

PAGE

Wolf, E. A., and Stair, E. C., paper by 350
Woodard, O., paper by 537
Woody ornamental plants, effect of mulches and crops on growth of 517

Yarnell, S. H., paper by 375
Yeager, A. F., and Rasmussen, E. J., paper by 157
and Richards, M. C., paper by 263

Zielinski, Q., paper by 143